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REHABILITATION OF VISUAL FUNCTIONS IN PATIENTS WITH POSTCHIASMIC LESIONS OF THE VISUAL PATHWAYS AND CORTICES.

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Rehabilitation of Visual Functions in Patients with Postchiasmic Lesions of the Visual Pathways and Cortices

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ABSTRACT

Review of the studies on specific training for the remediation of visual field deficits and scotomata due to postchiasmic lesions of the visual system (Zihl & von Cramon, 1979c, 1982) reveals a need to systematically document the improvement of "everyday" tasks such as reading and other behaviours dependent on vision.

This study evaluated the effects of light threshold training on visual field functioning, sensory thresholds, grip strength, reading, and tasks thought to evaluate "everyday" vision. Nine subjects were studied over 17 experimental sessions using single-case methods and elements of group methods.

The results indicated that light threshold training improves light target detection. There was also evidence that some forms of reading were performed more quickly, though this did not generalize to all reading tasks. As expected, there was no treatment effect on sensory thresholds or grip strength. There was also no treatment effect on formal visual field testing. Finally, there was little evidence on measures of "everyday" vision that light threshold training improved either the speed or performance level on tasks that require vision.

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CHAPTER ONE

INTRODUCTION

The introduction of this dissertation will consist of a historical overview of the experimental and theoretical papers relevant to the study of residual visual functioning following lesions to the central nervous system. The first area discussed will be the historical roots of the current conceptualization of the localization of vision in the brain. Brief mention will be made of the experimental methods used and the conclusions reached by these early investigators.

The second focus of the introduction will be a synopsis of cerebral blindness and of the residual visual capacities in scotomata due to lesions involving the central nervous system, which will facilitate later discussion of patients who are struggling with visual deficits following brain damage.

The final section of the introduction will review the current research on the systematic training of residual visual capacities in scotomata due to lesions involving the central nervous system, and the restitution of visual functions to these reportly "blind" portions of the patient's visual field. The review of the literature on the remediation of visual field deficits will provide the framework for the major thrust of this dissertation, specifically a careful investigation of the improvement of "everyday" visual capacities in these patients following light threshold training. Furthermore, any change in the size of the visual field scotomata will also be evaluated in an attempt to replicate Zihl and von Cramon's (1979c, 1982) findings which suggest that the size of visual field deficits can be reduced with training.

Definition of terms

Prior to a review of the literature, there is a need to define several terms with respect to their use in this dissertation. First, "everyday" vision is a term used by Zihl (1981a, 1981b) to refer to such tasks as reading, visual orientation and the ability to walk using visual cues. In this study, several measures (measures of neglect, visual search and scanning) have been selected to estimate "everyday" visual ~~skills~~, and are termed "vision-dependent" behaviours. Secondly, the term scotoma needs clarification. The term scotoma refers to an area of impaired or poor vision that is surrounded by relatively unimpaired or good vision. A scotoma is always relative to the specific method of testing the visual field. For example, one may show a visual field defect when tested with a light target of a low intensity and show no defect with a brighter light target. When testing methods differ, as in the kinetic method of Goldmann fields compared to the static method of the auto perimeter, one will also see differences in the size and shape of the visual field scotoma. Thus, a visual field defect will always be dependent on the assessment method used to study it.

Finally, the term "blindsight" is one that has recently been frequently used in the study of visual field deficits and should be defined. Briefly, blindsight typically refers to those visual capacities that remain in an area of scotoma. The development and appropriateness of this term will be discussed further, when we discuss those studies which investigate visual functions in patients with large field defects due to lesions of the geniculostriate visual pathways.

Historical background

Relatively early on, it was observed that experimental animals and patients with brain lesions did not always suffer a lasting loss of vision following brain damage to sites thought necessary for visual processes. However, agreement on this was not universal. Cortical functions were interpreted from either a localistic or holistic point of view. For example, von Monakow (cited in Hecaen & Albert, 1978) suggested in 1914 that the loss of vision due to a cortical lesion was only transitory, based on his observations of experimentally lesioned animals. In contrast, the clinical observations of Holmes and Lister

(1916), Poppelreuter (cited in Teuber, Battersby, & Bender, 1960), and Wilbrand and Sanger (cited in Teuber et al., 1960) suggested that visual field defects were permanent following the first few days or weeks after the lesion.

One reason von Monakow suggested there was no permanent loss of vision following a brain lesion was that he believed there was no localizable cortical site that was critical for the representation of the visual field. This belief was partly based on the earlier work of Flourens who, according to Boring (1957), was one of the most influential historical figures in advancing the understanding of brain behaviour relationships.

For Flourens, the central nervous system could be divided into six subdivisions for experimental study. These subunits consisted of the: 1) cerebral hemispheres, 2) cerebellum, 3) corpora quadrigemina, 4) medulla oblongata, 5) spinal cord, and 6) the nerves. Of particular interest for localizing visual functions are Flourens' experimental results following the removal of the cerebral hemispheres. He found that though the experimental animal does not respond to ordinary visual stimuli, it does demonstrate pupillary constriction and sensory discrimination. Thus, for Flourens the hemispheres were needed for "perception" but not for sensory discrimination. Furthermore, Flourens believed the corpora quadrigemina necessary for normal vision because, following lesions to this structure, Flourens found the animals behaviourally blind (Boring,1957).

In summarizing Flourens' position, he thought that the various parts of the nervous system had specific properties or functions and distinct effects resulted from their removal. However, despite the diversity of these properties there remained a unitary system. Thus there were specific functions and a larger unit operating simultaneously. Furthermore, Flourens thought that the removal of any portion of the system would result in reduced ability for every other part of the system. He stated:

> "One point excited in the nervous system excites all the others; one point enervated, enervates them all; there is a community of reaction, of alteration, of energy. Unity is the great principle that reigns; it is everywhere, it dominates everything. The nervous system thus forms but a unitary system" (Boring, 1957).

From this it is apparent that Flourens anticipated Lashley's (1929) conception of mass action and of equipotentiality based on his own work as well as on that of Franz's (1915) studies of cerebral function. These studies were primarily based on the extirpation, or ablation, method of experimental investigation developed by Flourens, and the reliance on this technique no doubt heavily influenced the conclusions. Furthermore, it might be mentioned that

Flourens' studies, published in 1824, furnished the basis for others such as Hughlings Jackson in the late 1800's and Henry Head in the early 1900's, who also opposed exact localization of function in the nervous system.

Other early investigators, using different experimental methodologies, tended towards a more precise localization of functions. For example, studies made by electrical stimulation of the cortex conducted by Fritsch and Hitzig (1870) led to the localization of motor functions. This experimental method has continued to date, providing useful information about localization (Fedio, 1980; Fried, Mateer, Ojemann, Wohns, & Fedio, 1982; Ojemann, 1982; and Penfield & Roberts, 1959).

Ferrier (1878), using both ablation and stimulation methods, was the first to localize the visual centre in the occipital lobes. He found that when one occipital lobe was removed in the monkey, the animal developed abnormal eye movements and acted as if blind in the eye contralateral to the side of the lesion. Munk (cited in Teuber et al., 1960) refined this observation in 1881 showing that the unilateral removal of the occipital lobe (in the experimental animal) did not cause complete blindness in either eye, but rather produced a hemianopia of the contralateral visual field.

In 1882, two important human cases were reported in detail by Haab and Hugenin (cited in Lindenberg, 1977). These two patients were found to have homonymous hemianopia prior to their deaths. At autopsy, the calcarine cortex contralateral to the side of the hemianopia was involved. In one case, the damage was caused by a tuberculoma, and in the other by an infarction of the visual cortex. Haab and Hugenin concluded that the cortex, characterized by the white stripe described by Gennari in 1782, must be the centre of vision. This was the first report which recognized Gennari's stripe as a gross visual indicator of the extent of the visual cortex in humans. Henschen (cited in Teuber et al., 1960) presented further evidence, in 1900, on localization when he demonstrated that the upper half of each retina is represented in the upper bank of the calcarine fissures and the lower half of each retina is represented in the lower walls of the calcarine fissures. Following this, Holmes and Lister (1916) added detailed clinical reports which localized the macula (the area in the retina responsible for foveal vision) to the extreme end of the occipital poles with more peripheral areas represented in the more anterior portions of the calcarine cortex. Thus, the findings of Munk, in 1881, were confirmed by those using "nature's experiments", otherwise known as clinical observation. The clinical studies on World War soldiers had the added credibility that their results were based on humans rather than the experimental animal. However, the fact that their findings seldom had firm anatomical autopsy confirmation of the brain areas involved in the lesion was an underlying weakness. Such workers as Holmes (1918a, 1918b, 1919a, 1919b, 1931, 1934, 1945), Holmes and Lister (1916), and Riddoch (1917), reported their findings on missile wounds to the head during World War I and helped map out the cortical representation of visual functions further. Work on World War II veterans conducted by Spalding (1952) and Teuber et al. (1960), added to the understanding of the localization of visual functions in the occipital lobes. This work has progressed to the point where few dispute the verity of localized representation of vision in humans, and yet problems remain.

In general, neuroscientists continue to search for, find and discuss sites of localized cortical functions, though seldom is there an explanation for what such a centre actually is. Typically, these researchers are connectionists, believing that the function of a nerve fiber is to transmit excitation from neuron to neuron, ultimately from a sensory organ to an effector. Based on this view, a localized centre is nothing more than a bottle-neck through which neuronal activation must pass, a cortical area so vital that the destruction of it dramatically impairs the function. With this understanding of localization of function, it makes good sense. However, the argument that these locations are the "seat" of, or the ultimate source of, the brain function is tenuous. Thus, the study of the recovery of function, following destruction of those sites believed critical for the function becomes all the more interesting and vital to our understanding of how the unitary system, made up of many parts, or inter-connections, operates normally.

Cerebral blindness and residual vision

This brings us to the next section of this introduction, that of cerebral blindness and the residual capacity for vision in "blind" areas of the visual field. The degree and extent of lasting visual deficit in cerebral blindness has aroused controversy. It has traditionally been taught that total destruction of the human geniculostriate visual pathways should lead to a complete and permanent blindness "equivalent to a bilateral enucleation or to bilateral optic nerve atrophy" (Magito & Hartmann's 1927 report, cited in Hecaen & Albert, 1978). Thus, this viewpoint suggests that cerebral blindness is, in a sense, a bilateral hemianopia resulting from the destruction of postchiasmal visual pathways. This teaching stands in direct contrast to what is known to occur in the complete ablation of striate cortex in subhuman primates. In ablation studies conducted on non-human primates it has been shown that many visual functions return following striate (or primary visual) cortex excisions including pattern discrimination and spatial localization of objects (Humphrey, 1970; Kluver, 1942). There have also been repeated attempts to show that as one moves up the phylogenetic scale, the organism becomes more dependent on the integrity of the cortex for visual processes (Marquis, 1934, 1935; von Monakow, 1914). This is known as the "encephalization hypothesis", and suggests that phylogenetic development has led to the progressive "take-over", by cortical regions, of functions previously controlled by subcortical structures. This hypothesis ~~attempts to arrange~~ the observations on subhuman forms, made by those such as Kluver (1927, 1941, 1942), Munk (1881), and Panizza (1855), together with the clinical observations made by those such as Holmes (1919) and Holmes and Lister (1916), into a meaningful theory. The theory of progressive encephalization has been thought by some to be inaccurate as a result of more recent evidence, first provided by Schneider (1969), that suggests there are at least two visual systems.

Schneider's (1969) experiments on the golden hamster showed that lesions of the visual cortex resulted in visual deficits that were qualitatively different from those following superior collicular or tegmental lesions. The first, or geniculostriate visual system, was proposed as the system that allowed the animal to know **what** things were visually and the second, or subcortical visual system, was thought to be the system that mediated information on **where** things were spatially. Furthermore, it was hypothesized that these two systems remain similar in all species, including the higher primates and humans.

This theory predicts that complete cortical blindness should not occur in humans following the destruction of the geniculostriate visual system and, in fact, there is evidence which suggests that total blindness is not lasting in humans following such lesions (Gassel & Williams, 1963; Marie & Chatelin, 1915; Teuber et al., 1960).

At this juncture, perhaps some explanation of the terms "blind" and "blindness" is warranted. As discussed by Knudson and Cumming (1958), the word "blindness", as currently used, is not an absolute term for total absence of eye sight, especially in legal matters. For example, even the current income tax laws allow partially seeing individuals to be considered blind for taxation purposes. According to the logic of the term, however, there can be no "partial" blindness. The concept towards which the term, partial blindness, is directed is actually the idea of partial sight. Thus, degree of blindness is also a misnomer directed toward the concept of the degree of vision remaining. Yet, because of the implied paradox in speaking of partial sight and degree of sight among those who are termed "blind", the terms "partially blind" and "degree of blindness" are often used. Basically, when one speaks of someone being blind, one refers to the fact that these individuals are without useful sight or have no useful light perception. Furthermore, alterations in visual processes can range from subtle to severe disturbances of discrimination or object recognition. Thus, the investigator's task is not only to detect these changes but also to determine the nature, quality, and extent of sight remaining in the "blind" portions of the visual field. In demonstrating a scotoma the investigator uses a definite procedure (Milner & Tueber, 1968). The scotoma demonstrated on perimetry testing represents an area in the patient's visual field where he or she is unable to discriminate the presence or absence of a specified stationary or moving light target presented under strict specific conditions. A different background illumination, a larger, smaller or brighter target, or a moving versus a stationary target may reveal a scotoma of a different size or contour depending on the assessment technique. It should, therefore, be apparent that the precise extent of any given field defect or scotoma is a function of the defining stimulus conditions. A scotoma may exist for only very small or dim targets or appear as only a relative scotoma on prolonged inspection of small stationary targets (Milner & Tueber, 1968).

The residual visual capacity of regions thought "blind" based on standard perimetric test results has been termed "blindsight" by Weiskrantz, Warrington, Sanders, and Marshall (1974). We shall discuss "blindsight" in more detail below. However, we now return to the issue of cerebral blindness. Cerebral blindness may occur in stages, beginning with a hemianopia, which later develops into a purported complete blindness. It may also occur as a paroxysmal event, as in an epileptic event, migraine, or transient ischemic attack (Hecaen & Albert, 1978). Blindness following head injury may also develop. However, post-traumatic blindness is usually temporary in nature (Teuber et al., 1960). Cortical blindness is generally found to endure longer following vascular events (Bergmann, 1957; Monbrun & Gautrand, cited in Hecean & Albert, 1978), and has been reported to last for up to several years (Brindley, Gautier-Smith, and Lewin, 1969; Brindley & Janota, 1975; and TerBraak, Schenk, & Van Vliet, 1971). Diffuse lesions such as those present in leukoencephalitis, demyelinating diseases, carbon monoxide poisoning, and anoxia, have also been reported as resulting in cerebral blindness (Hecaen & Albert, 1978). Anoxia is one of the more frequent causes, though its effects are generally reported as more transient than the cerebral blindness observed following vascular events (Barnet, Manson, & Wilner, 1970).

Another problem with studying patients with cerebral blindness is that some present with "anosognosia," or Anton's syndrome (Anton, 1899, cited in Hecaen & Albert, 1978). This phenomenon refers to the patient's denial of a visual field defect. The presence of such denial requires evaluation, otherwise one may be misled to believe that the field defect has resolved.

The recovery sequence in cerebral blindness has been documented as following a predictable pattern (Gloning, Gloning, & Hoff, 1968). First, there is light perception, then discrimination of movement, then colours, and finally forms. The recovery of colours and forms may return at the same time or over a longer period with different recovery rates. Pötzl (cited in Hecaen & Albert, 1978) reported, in 1928, three stages of recovery, as follows: 1) the sensation of darkness; 2) the perception of greyness and blurry-hazy objects, scintillating sensations with colours appearing washed out (the perception of red returns first, blue colours return last); and, 3) blurry vision similar to myopia, diplopia with difficulties of fusion, rapid fatigability, and problems with object discernment similar to elements of dyslexia or agnosia.

The remarkable and frequently documented recovery of visual functions following lesions to regions of the visual cortex returns our discussion to the consideration of "blindsight", a concept introduced above.

Sanders, Warrington, Marshall, and Weiskrantz (1974), and Weiskrantz et al., (1974) were the first to use the term "blindsight". They used it to describe visually guided behaviour mediated by stimuli falling within an area of the visual field that was considered "blind" following assessment on traditional methods of perimetry. The results obtained from the study of experimental animals (Cowey & Weiskrantz, 1963; Humphrey, 1970; Kluver, 1942; Mohler & Wurtz, 1977) provided the groundwork for most of the clinical studies that were later carried out on humans. These studies with animals suggested that, with specialized techniques, one could demonstrate the recovery of visual functions following cortical ablation of primary visual areas. This developed further the notion that subcortical visual centres played an important role in the return of these processes.

The experimental evidence from these animal studies suggested to others (Poppel, Held, & Frost, 1973; Torjussen, 1976; Zihl & von Cramon, 1979c, 1982) that it was time to challenge the traditional view that lesions to human striate cortex resulted in complete and permanent blindness or visual field defects.

Poppel et al., (1973) were the first to report that the ability to localize visual stimuli falling within the scotoma remained for human patients with visual field defects. This was later confirmed by others (Barbur, Ruddock & Waterfield, 1980; Perenin, 1978; Perenin & Jeannerod, 1975, 1978; Perenin, Ruel, & Hecaen, 1980; Weiskrantz, 1980; Weiskrantz et al., 1974; Zihl, 1980a, 1980b, 1981; Zihl & von Cramon, 1979c, 1980, 1982). Earlier work by Bender and Krieger (1951) and Williams and Gassel (1962), had also demonstrated the ability to localize targets in blind regions of the visual field, though these studies were not directed specifically to investigate the ability to localize targets, or were poorly designed to do so.

There are other investigators who have not entirely agreed that patients with field defects can localize targets in their scotomata. For example, Meienberg, Zangemeister, Rosenberg, Hoyt, and Stark (1980) studied three patients with hemianopia who were unable to localize targets using saccadic eye movements. Perinen et al. (1980) found that the case they studied gave equivocal results when attempting manual localization of targets. Barbur et al. (1980) also found ambiguous results with the single hemianopic patient they studied on a verbal localization task. Furthermore, there are those who have argued that the phenomena of "blindsight" are more easily explained as effects of scattered light, spared cortex, or near threshold visual processes (see Campion, Latto & Smith, 1983 for a detailed review). This contrasts with the two visual system hypothesis, which suggests that "blindsight" is mediated by subcortical visual centres. Still, others have reported that specific training can not only shrink the size of scotomata, but can also bring a return of normal visual processes (Zihl, 1981a, 1981b; Zihl, Krischer, & MeiBen, 1984; Zihl & von Cramon, 1979c, 1982; Zihl, von Cramon, Brinkmann, & Backmund, 1977; Zihl, von Cramon & Poppel, 1978). This brings us to the next section of this introduction - a review of studies that have attempted to remediate visual functions following brain damage.

Recovery and rehabilitaion of vision

Several training methods have been employed that reportedly improve the visual and perceptual deficits that follow brain damage (Diller et al., 1974; Diller & Weinberg, 1977; Lawson, 1962; Webster et al., 1984; Weinberg et al., 1979; Young, Collins & Hren, 1983; Zihl, 1981a, 1981b; Zihl, Krischer, & Meißen, 1984; Zihl & von Cramon, 1979, 1980, 1982; Zihl, von Cramon, & Poppel, 1978). The recovery of function in blind visual fields has been reported by Zihl to occur under at least five specific conditions: 1) improved spatial location of targets with practice of saccadic eye movements (Zihl, 1980); 2) improved saccadic localization with prior training in "registration" (or practice at detection) of light targets (Zihl & von Cramon, 1980); 3) recovery of normal visual processes by training in saccadic localization (Zihl, 1981a, 1981b; Zihl & von Cramon, 1982); 4) improved reading speed and accuracy, and increased parafovial vision, by training patients with hemianopic "dyslexia" before a television screen displaying words at varying speeds and levels of complexity (Zihl, Krischer, & MeiBen, 1984); and, 5) the recovery of normal visual processes (e.g., walking using visual cues, improved reading, and patient-reported improved vision) following a training of visual threshold. This latter training technique consisted of measuring, at different degrees of arc from central vision, the visual threshold for varying light intensities (Zihl & von Cramon, 1979a, 1979c, 1982; Zihl, von Cramon, & Poppel, 1978).

The recovery of "normal" visual processes following the use of the light threshold training technique used by Zihl and his collegues (Zihl & von Cramon, 1979b, 1979c, 1982; Zihl et al., 1978) is the main topic of this dissertation and will be examined in more detail.

In the first report published in English, Zihl and von Cramon (1979c) studied 12 patients with visual field defects due to postchiasmatic lesions, most of whom had suffered cerebrovascular accidents. The time between the onset of the training following the lesion causing the visual field defect ranged from one month to five years. The training consisted of a technique similar to one used by Cowey (1967) and Mohler and Wurtz (1977) to train monkeys on visual tasks following experimental brain lesions to striate visual cortex. The result found with monkeys, as reported above, was an apparent complete resolution of all visual deficits.

The training sessions for Zihl and von Cramon's patients (1979c) lasted approximately one hour, with a total of about 30 sessions for each subject. Contrast sensitivity training was conducted on the border of the scotoma, and the pattern that obtained was initially a decrease in sensitivity during the first few training sessions. Following this initial decrease in performance, improvement was the general rule, with an apparent reduction in the size of the visual field defect. Based on the data presented in this and other studies by Zihl (Zihl, 1981a; Zihl & von Cramon, 1982), it was evident that more than two-thirds of the improvement that occurred in these patients was realized within the first 6 experimental sessions. Patients also reported improvement in other visual functions, including dramatically improved walking using visual cues, colour perception, form perception, and the ability to read a newspaper.

A more recent study by Zihl (1981a) used a training technique which consisted of trials where light targets were presented in the periphery near the border of visual field defects. Subjects were then required to move their eyes from a central fixation point to the light target in one saccade. Results were reported on 14 patients, with the apparent outcome that the visual field increased in size from 2 to 24 degrees of visual arc. This study is also interesting because, again, Zihl remarks on the improved visual performance of these patients with respect to their "everyday" living demands on vision, and specifically notes with respect to reading:

> "...patients with the field border near the vertical axis (prior to training) who had problems reading longer words (because they appeared cutoff) or finding the beginning of the row when the left hemifield was affected, reported a distinct improvement in reading after training, even though they still had to look very carefully at longer words, and their speed of reading was still diminished as compared to the speed before they suffered from cerebral damage. However, their subjective reports of improved reading have not yet been objectively assessed" (Zihl, 1981a).

The recognition by Zihl (1981a) of the need for the objective and systematic documentation of improved "everyday" visual performances in these subjects, with special reference to reading, is an important concern and one which this dissertation attempts to address. However, one other factor not mentioned in Zihl's work is the relationship of the visual field defects and brain lesions to other neuropsychological functions. For example, there are several possible underlying mechanisms implicated with impaired reading or dyslexia (Hecaen & Kremin, 1976). A visual field scotoma is only one of these.

The results of Zihl and von Cramon (1979c) serve as a very good pilot study. However, it appears that they have not controlled several important factors that should be taken into account if one is to conclude that light threshold training is of benefit for restoring normal visual processing. For example, the role of neglect or attentional variables is no doubt important. Others (Lawson, 1972; Weinberg et al., 1979; Young et al., 1983) who have studied improved performance in reading following brain lesions placed importance on visual scanning tasks that directed the patient's attention to neglected regions of the visual field. Williams and Gassel (1962) also point out that the extent of the functional visual field can be dramatically altered by using techniques that direct the patient's attention to the affected visual field. In fact, Zihl and von Cramon (1979c) remarked that the degree of improved sensitivity found in the scotoma depended heavily upon directing the patient's attention to the area of visual field being trained. Additionally, early work by Zihl (Singer, Zihl, & Poppel, 1977) suggests that selective attention is directly related to visual field thresholds. Thus, any study attempting to repeat Zihl and von Cramon's work will need to monitor the possible role that neglect or other attentional variables play in the initial assessment of the field defect as well as in the documentation of improved functioning.

Zihl and von Cramon (1979c; 1982) did not control for other neuropsychological variables such as subjects' intellectual, verbal and performance abilities prior to their training. The study reported in this dissertation attempted this by collecting data on the intelligence, verbal comprehension and verbal fluency abilities of subjects prior to the threshold training.

There is also the obvious need to evaluate the influence that practice has on the various measures of visual field functioning. More important, there is the need to objectively assess the reported improvements in "everyday" vision. Zihl and von Cramon (1979c) relied on subjects' testimonial reports of improvement as evidence of the effectiveness of their training. The fact that their work has received attention from a diverse range of professionals and is becoming more frequently quoted in the literature (Bakker, 1984; Ellenberger, 1980; Finger & Stein, 1982; Miller, 1982; Rourke, Bakker, Fisk, & Strang, 1983) as a model for recovery of function following brain lesions, underscores the need for further study and replication of Zihl and von Cramon's work.

One attempt to replicate Zihl's finding of expanded visual fields following training has been very recently reported and merits comment. Balliet, Blood and Bach-y-Rita (1983) trained 12 subjects with field defects using both light threshold and saccadic localization methods. Four of the 12 subjects reported "very noticeable" expansions of their fields. Two were unsure of field changes. The remaining 6 subjects indicated that their visual field had not changed with training. Objective measurement of all subjects' fields revealed "no significant change in the size of visual field functioning." The possible effect these training methods had on other abilities requiring vision were not assessed. This study will be discussed further in the final chapter of this dissertation.

The current controversy in the literature regarding the brain region or sites responsible for such recovery is of obvious theoretical interest. However, the important clinical question is: **Can training patients with visual field defects improve their vision-dependent behaviour?** Whether this improvement represents functions of spared striate cortex, reorganization of surrounding cortical areas, or the assimilation of these functions by subcortical visual centres in the midbrain is secondary and impacts only minimally on the clinical significance of demonstrating improved vision in the individual patient. Towards this end, this dissertation will employ a single-case study methodology that allows for a detailed evaluation, over time, of each subject. It also includes elements of a group design that provide for an analysis of possible treatment effects.

STATEMENT OF THE PROBLEM

Basically, this study is designed to evaluate change in visual field deficits following light threshold training. Furthermore, the intent is to examine the effect that this training has on reading and other skills that require vision. Repeated assessments of abilities that do not require vision (i.e., two-point sensory thresholds and grip strength) have been added to help control for practice effects and to examine whether light threshold training is independent of other skill domains. Thus, evaluation occurs in the following areas:

1) After initiating light threshold training, there will be a clinically significant improvement in the patient's visual field deficit, demonstrated by an increase in the number of light targets detected during repeated auto perimetry.

2) Light threshold training will have no effect on repeated measures of sensory and motor functioning, demonstrated by no significant change on two-point sensory discrimination and grip strength.

3) Following the initiation of light threshold training, there will be a clinically significant improvement in repeated measures of reading speed and accuracy, demonstrated on an experimental reading task and on three standardized reading tests.

4) Light threshold training will increase the size of the functioning visual field measured by formal testing on the Goldmann Perimeter.

5) Those who receive light threshold training will demonstrate improvement on measures thought to evaluate "everyday" vision.

In each case, the null hypothesis will be evaluated.

CHAPTER TWO

METHOD

Subjects

Nine patients from the Division of Neuro-Ophthalmology at the Henry Ford Hospital, Detroit, Michigan, volunteered and completed this study. They were selected in the following manner: All files since the Neuro-Ophthalmology service began in September, 1980, were reviewed for patients with postchiasmic or geniculostriate lesions which resulted in visual field scotomata. The total number of files was 1,620. From this subject pool, 69 cases were identified as suitable subjects for this study. The next step was a review of the medical records of these patients. From the medical records, it was learned that 4 of the patients had died, 2 were reported "untestable" by Ophthalmology on Goldmann visual fields due to "inappropriate" behaviour, and 2 were reported as "mute" following their respective brain lesions. Of the remaining 61 patients, 13 had moved away from the area and, following three phone calls and one letter to each, 16 patients could not be contacted.

The remaining 32 patients were contacted for this study. Of these, 3 reported that they had no transportation to the hospital, 6 indicated that they were too ill to attend, 2 denied they had any problems (one reported new glasses had resolved all visual difficulties), and 9 patients refused for various reasons (e.g., "too busy" or "not wanting anything experimental").

The remaining 13 patients agreed to be included in the study. Of these 13, 2 patients failed to attend two different appointment times and 2 of the remaining 11 cases dropped out. Of the 2 patients who dropped out, 1 dropped out after the first session, and the second dropped out after the third session. An attempt was made to determine why these patients had dropped out. Only the patient who dropped out after three sessions was available for comment. She reported that the sessions were too lengthy, given her child care responsibilities and the distance of the hospital.

The 9 subjects who completed this study were heterogeneous on several relevant attributes (see Table 1), although there were more males than females represented.

Each of the 9 subjects was given an identifying code, after being randomly assigned to either series one or series two of the experimental sessions in the multiple baseline design. In series one, light threshold training was initiated early, following a brief baseline. Thus, the subjects in this series received a code with an "E" for Early. Those subjects assigned to series two had a more lengthy baseline period, which meant that they received the training relatively later than those in series one. Thus, patients in series two were given a code with an "L" for Late. This system of codification (i.e., Early vs. Late) is similar to the approach others have utilized to organize subjects and aids in later data interpretation (Gianutsos & Gianutsos, 1979). For a concise summary of subject information, Table 1 is presented.

Insert Table 1

E1 was a 24-year-old, left-handed, Caucasian female. She was employed as a business secretary, and lived with her mother. E1 was first seen for this study approximately 12 months following surgery for a right parietal occipital arterial venous malformation [AVM]. Prior to this study, she judged her "overall" visual abilities as "9" (on a scale from 1 to 10, with 10 being "the best your vision has ever been"). However, when questioned at the end of the study, she indicated that her vision was "a 7 or 8" at the beginning of the study, and improved to a "9". Her past medical history revealed that her health was unremarkable until 1977, when, shortly after playing basketball, she experienced an onset of neck pain, pounding behind the eyes, and the onset of nausea. Following this, she developed back pain and received a spinal tap which proved to contain blood. No further evaluation or event occurred until October

TABLE 1

Patient Information

Subjects:	E1	E2	E3	E4	L1	L2	L3	L4	L5
Age:	24	58	65	36	51	27	37	57	59
Sex:	F	M	M	M	M	M	M	M	M
Handedness:	L	R	R	R	L	L	R	R	R
Full Scale IQ:	117	123	104	114	96	100	83	102	139
Verbal IQ:	123	124	107	122	116	108	79	94	130
Performance IQ:	106	118	99	102	70	89	89	112	147
Token Test:	84	84	84	84	81	81	78	82	84
Oral "D's":	18	13	8	19	19	11	8	10	16
Education:	14	18	8	13	16	16	12Sp.	8	18
Income:	16	100	14	33	12	25	10	11	45
Mos. From Lesion:	12	19	7	38	16	18	162	26	19
Site of Lesion:	RPO	LO	LO	RPO	BIL	RPO	BIL	LO	LO
Lesion Type:	AVM &Sg.	CVA	CVA	AVM &Sg.	CVA &Sg.	TUM &Sg.	MVA	CVA	CVA

Table 1. E1-4 = Early treatment subjects, L1-5 = Late treatment subjects. Education reported in years, Sp.= Special education. Income reported in thousands.
Site of Lesion: RPO = Right-Parietal-Occipital, LO = Left-Occipital, BIL = Bilateral or Generalized. Lesion Type: AVM = Arteriovenous Malformation, CVA = Cerebral Vascular Accident, MVA = Motor Vehicle Accident, TUM = Tumor, Sg. = Surgery.

4, 1983, when, after playing racquetball, she developed a stiff neck and awoke late in the evening with pounding behind her eyes. Following admission to hospital, she again had a bloody spinal tap and then received an angiogram, which revealed a right parietal occipital AVM. Further studies at Henry Ford Hospital indicated the AVM to be in the deep medial right parietal lobe medial to the atrium, at about the level of the splenium. A right parietal occipital craniotomy was performed (August 14, 1983) and the AVM was excized. She demonstrated good recovery and was discharged home with the final diagnoses of: 1) right parietal AVM and, 2) left homonymous hemianopsia. Her visual fields were evaluated postoperatively, and the results revealed that they had improved from an initial left hemianopsia to normal Tangent Screen fields in April, 1984. However, she continued to report mild visual problems off to the left, and a "left visual field cut" was reported on formal Goldmann visual field testing.

E2 was a 58-year-old, right-handed, Caucasian male. He recently received a medical retirement from an administrative position in the automotive industry, and lived with his wife. E2 was first seen for this study approximately 19 months after an apparently small infarction involving his left occipital lobe. Prior to this study, he judged his "overall" visual abilities as "5" on a 10-point scale. However, when questioned at the end of the study, he judged that his vision was "3" at the beginning and "3" at the end, reporting that he "could not really define a particular benefit" or change. His past medical history included colon cancer which metastasized to his liver and was treated twice with surgery since 1981. In March, 1983, he felt ill and went home to sleep. When he awakened, he noticed trouble with his vision. Upon examination, there was a right homonymous hemianopsia (greater above) to confrontation testing. On the Goldmann fields there was a congruous right upper quadranopsia. He was hospitalized recently (June 14, 1984) for a two-day work up for an apparent syncopal episode, and his final discharge diagnoses were: 1) syncopal episode, 2) history of colon cancer, 3) hypertension, 4) status post thrombotic infarction to vertebral basilar distribution, with residual left upper quadranopsia field defect. This field defect remained stable, according to both patient-report and formal field testing, since first noticed in March, 1983.

E3 was a 65-year-old, right-handed, Caucasion male. Prior to retirement, he was employed as a bus driver. He has lived alone since his wife's death several years ago. E3 was first seen for this study seven months following occlusion of his left posterior cerebral artery, which resulted in a right homonymous hemianopsia. Prior to training, he judged his "overall" vision as "5" on a 10-point scale. This was also his judgment, following the study, of where his vision was at the beginning. However, he reported that after the threshold training, his vision improved to about a "7". His past medical history revealed that he suffered a myocardial infarction in 1977, and he has had a history of gout and hypertension. He was admitted to hospital on June 6, 1984, when he suddenly noted an inability to see out of his right eye. He reported that he had a "visual sensation of darkness". He drove home with his girlfriend sitting to his right to guide him. He had no slurred speech, dizziness, perioral numbness, nausea, headache, pain, dysarthria, or weakness in his extremities. A four-vessel transfemoral cerebral arteriogram was done and showed evidence of "occlusion of the left posterior cerebral artery in its circumesencephalic portion with failure of visualization of its distal branches." He was discharged home on June 15, 1984, with the final diagnoses: 1) occlusion of left posterior cerebral artery with infarction of the left occipital lobe; 2) right homonymous hemianopsia; 3) hypertension; and, 4) obesity. His visual fields were formally examined while hospitalized and again, prior to the light threshold training study. The results showed a dense right homonymous hemianopsia with little change since his infarction.

E4 was a 36-year-old, right-handed, Caucasion male. Trained as a millwright, he was employed as a robotics programmer in the auto industry. He resided with his wife and two sons. He was first seen for this study approximately 38 months following surgery for removal of a right parietal AVM, which had hemorrhaged. Prior to this study, he judged his overall vision as a "5" on a 10-point scale. At the conclusion of this study, he judged his vision as initially a "4", which improved to a "6". His medical history revealed that he had two surgical procedures for a right parietal occipital AVM. The first surgery (November, 1981) excised the AVM. The second (June, 1982) was performed to control recurrent bleeding, and to evacuate a right parietal occipital intracerebral hematoma. A CT Scan prior to the first surgery indicated evidence of an AVM along the "medial aspect of the right occipital and posterior parietal cortical area". Prior to the second operation, a CT Scan showed an avascular mass, due to an "intracerebral right parietal occipital hematoma." At that time, an arteriogram also showed a "wedge-shaped area of relative avascularity" in the right posterior parietal area. Following the second surgery, he experienced "four or five" generalized tonic-clonic seizures, of durations up to one minute. He was placed on Dilantin and Phenobarbital, with good results. He has not experienced seizures since a brief hospitalization in August, 1982. However, he did report that he continued to experience infrequent severe headaches for which he took medication (Dalmane / Motrin). His most recent hospital discharge diagnoses included: 1) seizure disorder following status-post AVM excision; 2) right parietal occipital intracerebral hematoma evacuation; 3) left homonymous hemianopsia greater for the inferior quadrant. Formal visual field testing confirmed a stable field defect.

L1 was a 51-year-old, left-handed, Caucasian male. He was medically retired from a draftsman engineering position. He resided with his wife and teenaged children. L1 was first seen for this study 16 months following a cerebral vascular accident and bypass operation, which resulted in a bilateral homonymous hemianopsia. Prior to light threshold training, he judged his "overall" vision as a "2" on a 10-point scale. However, following the completion of the study, he judged his vision as "5" both before and after the training. His past medical history revealed that he sustained an early BB gun injury to the left eye. Since this BB gun injury, he has had little useful vision in that eye. He also reported a history of cervical myelopathy (C5-6), ulnar neuropathy, bilateral Dupuytren's (hand) contractures, diet-controlled diabetes mellitus, and hypertension, which he regulates with Inderal. He received an EC-IC bypass in August, 1983. Following this, he experienced one grand mal seizure and continues on anti-convulsant medication. Furthermore, a follow-up CT scan revealed "multiple small infarcts in the supratentorial compartment in the left frontal, left parietal, and both occipital cortices, as well as a moderately sized infarct in the right cerebellum". An EEG found "abnormal diffuse disturbance...affecting maximally the posterior head regions", although there was no evidence of seizure activity. While recovering from his bypass surgery, he was referred to psychiatry due to a "reactive depression" apparently associated with his "cerebral blindness" and "prosopagnosia". The psychiatrist made a referral to a speech pathologist for speech therapy. The patient discontinued both the psychiatric and speech therapies after approximately three visits, as he felt "they were not really helping". His final discharge diagnoses were: 1) status post multiple small infarcts, 2) bilateral vertebral stenosis with EC-IC bypass, 3) seizure disorder, 4) bilateral homonymous hemianopsia with cerebral blindness and prosopagnosia, and 5) reactive depression. Formal testing of his visual fields revealed progressive improvement since his bypass surgery, although the left eye has little useful vision due to the early BB gun injury, and the right eye continued to show evidence of the bilateral homonymous hemianopsia. His prosopagnosia has remained unchanged since the bypass surgery, and is reportedly the most devastating and frustrating of his current symptoms.

L2 was a 27-year-old, left-handed, Caucasian male. He was convalescing at the time of this study, and had previously been a university student in forestry. He resided with his parents. L2 was first seen for this study 18 months after a subtotal removal of a right posterior parietal astrocytoma (grade II or III), and approximately 16 months after completing radiation therapy. Prior to light threshold training, he judged his "overall" vision as "5" on a 10-point scale. However, after completing the study, he rated it as a "7" initially, which improved to an "8". Past medical history was clear until left-sided sensory seizures began in September, 1982. A follow-up CT scan revealed a right hemisphere hypodense lesion found to be an astrocytoma, which was subtotally excised on April 4, 1983. Radiation therapy was completed on June 20, 1983. He continued to make good recovery with no evidence of recurrent tumor on CT scan. However, he continued to have periodic seizures (primarily, minor sensory seizures) that affected the left side of his body. Formal visual field testing revealed post-operative evidence of a left lower quadrant field cut. Following radiotherapy, his visual field test results revealed very little improvement from post-operative testing, reporting a stable left lower quadranopsia.

L3 was a 37-year-old, right-handed, Caucasian male. He was financially supported by his parents and social assistance. He has always lived with his parents. L3 was first seen for this study approximately 13.5 years after he sustained head injuries in an automobile accident. He initially judged his overall visual abilities as "7" on a 10-point scale. After the light threshold training, he reported that he initially judged his vision as a "6", and that, over the course of the study, it improved to an "8". His past medical history revealed that, when nine months old, he developed left-sided seizures which worsened at age 14. With time, these became primarily nocturnal seizures, and were reported as being reasonably well-controlled with medication. When he was 22-years-old he was struck by an auto, which resulted in a "mild" blow to his head with no reported loss of consciousness. Recent CT scanning (October 18, 1983) was negative and, following extensive evaluations at both University Hospital, Ann Arbor and at Henry Ford Hospital, Detroit, his diagnoses were: 1) early onset of seizure disorder, likely, temporal lobe epilepsy; and 2) left homonymous hemianopic field defect of unknown etiology (but "suspect" right parietal lobe lesion). Formal visual fields were first administered at University Hospital in 1970 and he has had several exams since that time. The results from these indicated "an almost complete left homonymous hemianopic defect with questionable macular sparing". The patient reported no subjective change in his vision. Just prior to L3's involvement in this light threshold study, the above findings were confirmed on Goldmann visual field testing.

L4 was a 57-year-old, right-handed, Caucasian male. He was retired from 27 years as a forklift operator, and resided with his wife. L4 was first seen for this study 26 months following a minor cerebrovascular accident involving the left occipital lobe. He initially judged his "overall" visual abilities as "4" on a 10-point scale. Following the study, he judged that prior to light threshold training, his vision was "about a 5", and improved to a "6". His past medical history revealed diabetes mellitus (well-controlled with insulin), hypertension (controlled with medication) and arteriosclerotic cerebral vascular disease. While a child, he required surgical repair to his ring and middle fingers due to a lawn mower injury. There were several CT scans, and the most recent (February 7, 1984) indicated: 1) a small asymptomatic falcine meningioma of the left posterior falx in the interhemispheric fissure on the left side, which has been unchanged in size for the past 2 years; and 2) a small, well-defined area of decreased density in the medial visual cortex of the left occipital lobe. Formal visual field testing revealed a post-infarction visual field defect. On Tangent Screen testing there was a well-defined right homonymous hemianopsia sparing 10° of macular vision without steps or scotomata. On Goldmann fields, there was again a right homonymous hemianopsia with evidence of macular sparing.

L5 was a 59-year-old, right-handed, Caucasion male. He was retired from a supervisory position at a local international airport, and resided with his wife. L5 was first seen for this study 19 months following a small left occipital infarct. Prior to the light threshold training, he rated his "overall" vision as "7". At the conclusion of this study, he judged that it was initially an "8" and remained at "8" after the training. His past medical history was clear until June 17, 1983, when he noted a decrease in vision in his right visual field and a weakness of his lower extremities. He had a CT scan —which was negative; angiography showed only "some kinks at the origin of both vertebral arteries" and was otherwise normal. EEG was also normal. Formal visual field testing, however, revealed a right homonymous scotoma in the right visual field. The final diagnosis was that of a small discrete left occipital infarct involving primary visual cortex.

Experimental design

Auto perimeter target detection, sensory discrimination, grip strength, and the repeated numeral reading task designed for this study were evaluated with a single-case "multiple baseline across cases" design (Barlow, 1981; Hays, 1981; Hersen & Barlow, 1976; Kazdin, 1976, 1981, 1982). This technique has been used in previous studies on rehabilitation of brain-injured patients (Gianutsos, 1981; Gianutsos & Gianutsos, 1979, in press). The differential lag (Early vs. Late) in the implementation of treatment is a key feature of the multiple baseline design and with repeated measures for each subject, allows evaluation of treatment effects over time (see Table 2). This procedure was used to evaluate the repeated measures on the auto perimeter, sensory and motor tests, and repeated numerical reading.

Insert Table 2

Three "observation" days (O1, O2, and O3) were positioned within the 17 experimental sessions sequence. On O1, O2, and

TABLE 2

Experimental Design

Session:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Early:	01	C1	C2	L1	L2	L3	L4	L5	L6	02	L7	L8	L9	L10	L11	L12	03
Late:	01	C1	C2	C3	C4	C5	C6	C7	C8	02	L1	L2	L3	L4	L5	L6	03

Table 2. Sequence of the experimental sessions for the "Early" and "Late" treatment group. The "O" represents "Observation days" where standardized reading tests, Goldmann fields and vision tests were given. The "C" represents control sessions where one hour of supportive counselling occurred. The "L" indicates light threshold training sessions.

O3, standardized reading tests, formal Goldmann fields, and several measures of "everyday" vision were given (see Campbell & Stanley, 1963; and Cook & Campbell, 1979). The comparison that allowed evaluation of the treatment on these measures was the percent of change from O1 to O2. At this point in the experimental group the Early treatment group received six light threshold training sessions and the Late treatment group had received none (see Table 2). The null hypothesis for those measures given on O1, O2, and O3 was that there would be no significant difference on the standardized reading tests, Goldmann fields, and measures of "everyday vision" between the two groups' percent change scores from O1 to O2. Mean scores for the Early and Late treatment groups at O1, O2, and O3 were graphed and presented for visual inspection in Chapter Three.

In summary of the experimental design, hypothesis one, hypothesis two, and the experimental numeral reading task required an evaluation of the change in each single case from the baseline phase through the treatment phase. The evaluation of the standardized reading tests and of hypotheses four and five used a more traditional group analysis through examination of the percent change scores between the Early treatment and Late treatment groups at a time in the experiment when only the Early treatment group had received the light threshold training. Mean scores for these measures, for both groups, at O1, O2, and O3 were graphed and presented for visual inspection in Chapter Three.

Testing materials and methods

Interview: All patients received an initial and final interview which collected personal and medical histories. In both the initial and final interviews, patients were asked to rate their "overall vision" on a scale from 1 to 10, where 10 was to be considered "the best your vision has ever been." The initial interview also attempted to evaluate denial of visual field deficits in each subject (see Appendix A).

General intelligence: General intellectual abilities were assessed during the first session by an abbreviated Wechsler Adult Intelligence Scale [WAIS] (Wechsler, 1955) consisting of four Verbal subscales (Information, Similarities, Digit Span and Arithmetic) and four Performance subtests (Digit Symbol, Picture Completion, Block Design and Object Assembly).

Handedness: Handedness was determined during the first session by a modified questionnaire developed to assess lateral dominance (Annett, 1970; Coren, Porac & Duncan, 1979). All subjects were classified as either right- or left-handed based on their performance of at least 6 of 8 tasks with their preferred hand.

Language: Language comprehension was assessed by the administration of a shortened form of the Tokens Test (De Renzi & Faglioni, 1978). The total score possible for flawless performance was 84. Language fluency was evaluated by an Oral Fluency task which required subjects to name as many words as possible that began with the letter "D" in 60 seconds. It has been reported (Kimura, 1984) that most aphasic patients score fewer than 6 words, whereas the majority of non-aphasic patients score 12 words or more. Both language tests were administered during the first session.

Control or baseline sessions: During the control or baseline experimental sessions, each subject received approximately 40 minutes of supportive, non-directive counselling, and was encouraged to continue his or her physician's directives (see experimental design in Table 2). Then, repeated measures on an experimental reading test, sensory, motor, and auto perimetry were taken. These measures are described in detail below. Control sessions were approximately one and one-half hours in length.

Auto Perimetry: The Auto Perimeter Dicon 2000 by Cooper Vision Diagnostics of San Diego was used to assess the subject's visual fields during each of the 17 experimental sessions. This apparatus was described in detail by Aulhorn and Durst (1977). It was automated and only required the examiner to seat and instruct the patient (see photo in Appendix A). Fixed static test points, made of 312 computer-calibrated light-emitting diodes [LEDs], were spaced along 36 radials at 10° increments. The subject was instructed to depress a hand-held button as soon as a light target was detected. This allowed assessment of the two visual fields in each eye from 2.5° near central fixation to 80° of eccentricity. Measurement of the blind spot occurred at 7° below the horizontal of the 16° arc in each eye by a separate cluster of 21 LEDs. These targets were initially presented while the patient fixated a central target. This allowed the computer to determine the size and centre of the blind spot; this aided in checking fixation during the field test. If a target was detected in the blind spot during the field test, the preceeding 5 test targets were again presented in a random order. Visual monitoring of fixation by the experimenter was also maintained by way of a sighting periscope which aligned the patient's pupil with the central light target. Plots of the blind spot and visual field were printed for each of the 17 experimental sessions. For a detailed description of auto perimetery the reader is referred to Heijl and Drance (1981) and Heijl, Drance, and Douglas (1980). The size of the functioning visual field was objectively determined by calculating from the printed plots the percent of the light targets detected at a standard light intensity (160 apostilbs [ABS]).

Light Threshold Training: The light threshold training sessions utilized another computer program of the Auto Perimeter 2000 from Cooper Vision. The instructions were the same as for the visual field testing condition. The first portion of each trial consisted of assessing the location and size of the blind spot to monitor fixation. However, instead of the standard LED intensity and random activation of any target in the entire visual field, this program allowed the selection of a specific radial meridian (any 1 of the 36 radials spaced around the visual field at 10° intervals). It then randomly activated LEDs, from 2.5° to 80° of eccentricity along the selected meridian, beginning with a subthreshold intensity (12.5 ASB), and then increasing intensity by 0.1 log units until the patient correctly detected the target on two out of three trials, or until the target reached maximum intensity (at 8,000 ASB). This resulted in a printout of light threshold profiles along the meridian selected for each trial. This adaptation of Zhil and von Cramon's (1979c) light threshold treatment allowed the selection of a meridian which crossed a portion of the visual field defect in each patient. Once selected for each individual subject, the treatment meridian remained the same for each eye throughout the study. During treatment sessions, each eye received five threshold profiles along the selected meridian in the defective hemifield, and one threshold profile in a non-defective area of the field for comparison. Each treatment session required between one and one-half to two hours to complete, depending on the patient's need for rest periods, or his or her difficulties with fixation.

Sensory and Motor Tests: Sensory testing was accomplished by 17 repeated measures, (once per session) utilizing the two-point aesthesiometer obtained from Research Designs Inc. of Houston, Texas (see Corkin, 1964, for full description). The two-point sensory threshold was determined on each palm by administering a series of measures starting at 19 mm and decreasing by 2 mm until 2 errors out of 6 presentations occurred. The threshold was the smallest distance between the 2 points on which 1 or no errors were made. Motor testing of grip strength utilized the Smedley Hand Dynamometer manufactured by Lafayette Instrument Company. The score was the mean (in kilograms) of 2 trials per hand, and measures were taken during each of the 17 experimental sessions.

Reading: Reading was evaluated in several ways:

1) Repeated numeral reading was administered on each of the 17 sessions. This task was designed specifically to minimize the obvious practice effects encountered when subjects read the same material on 17 occasions. Scores on each subject were obtained by presenting five cards containing 20 two-digit numerals (e.g. "SIXTY-FIVE") for a total of 100 numbers (see Appendix A). The task required the patient to read the numbers as "quickly but as accurately as possible." The cards were presented in random order and the scores were: a) the times taken to complete the set of five cards and, b) the number of errors made. Subjects were allowed a maximum of 10 minutes tb complete the task.

2) The Chapman-Cook Speed of Reading Test was given on 01, 02, and 03 (Chapman, 1924). Form A was administered on 01 and 03. Form B was given on 02. This test consisted of 30 brief paragraphs where one word near the end of each "spoils the meaning of the paragraph." The subjects were required to cross out, as quickly and accurately as possible, the one word near the end of each paragraph which spoiled the meaning. For example: "It was such a cold, boisterous, and wintery day that every person who was walking wore the thinnest clothes that he could find in his clothes-closet at the time." One can see that the word "thinnest " does not fit the meaning of the rest of the paragraph and should be crossed out. The scores were: a) the number of correct items and, b) the time taken to complete the 30 paragraphs. Thirty minutes were allowed to complete this task. Percent change scores from 01 to 02 were then evaluated for statistical significance.

3) The Wide Range Achievement Test, Reading Subtest Level II (Jastak & Jastak, 1965) was given on 01, 02, and 03. This test consisted of 74 words. A slight change in the standardized manner of presentation required the subjects to attempt each of the 74 words. The test was discontinued after 10 minutes. The score was the number of words correctly pronounced, plus 15 points (maximum score = 89). The time taken to read the words was recorded. Percent change scores from 01 to 02 were evaluated for statistical significance.

4) Survey E of the Gates-MacGinitie Reading Test (Gates & MacGinitie, 1978), developed for grades seven through nine was administered. Form 1 was given on 01, Form 2 was given on 02, and Form 3 was given on 03. The test consisted of 43 multiple-choice questions based on 14 short paragraphs. The score was the number of questions correctly answered and the time taken to complete all questions was recorded. Those not finished in one hour were discontinued. Percent change scores from 01 to 02 were then calculated.

Goldmann Perimetry: The Goldmann perimeter was developed by Goldmann to obtain quality visual fields (Goldmann, 1945a, 1945b) and was the one selected for most clinical settings (Tate & Lynn, 1977). It was a dynamic field test, in that the targets moved either into or out of the field of vision. The patient pressed a button either as soon as the target was seen, or when it was no longer visible. Since it is known (Riddoch, 1917) that the detection of a moving target is easier than a static target, this measurement was less sensitive than that obtained on the Auto Perimeter and, consequently, assessed a slightly different visual function.

Goldmann visual fields were administered on 01, 02, and 03 (see experimental design in Table 2) by members of the Ophthalmology Department at Henry Ford Hospital who were blind to the nature of the study. Subjects were seated so that their eye being examined was 30 cm from the illuminated bowl, and various sized targets were presented. The sphere was illuminated by a single light source which varied in intensity. Central fixation was continually monitored via a centrally-placed fixation telescope. This examination allowed the Ophthalmology Department's staff to plot the subject's functional visual field by drawing "isopters" (or contour lines representing the limits of retinal sensitivity to a specific test target) for standard-sized targets. For a detailed discussion of this technique see Ellenberger (1980) and Tate and Lynn (1977). The charted Goldmann visual fields were then measured for each patient. This gave an area score (in square millimeters) for the most representative isopter and a percent change score was then calculated from O1 and O2.

Measures of "everyday" vision: The measures of everyday visual abilities consisted of five tasks which required, among other things, eyesight. Each is briefly described below:

1) A cancellation task developed to measure the degree of neglect (Diller et al., 1974; Young et al., 1983) was given on O1, O2, and O3. This test consisted of the letter "H" appearing randomly 105 times among a total of 312 letters typed on an 8.5 in. by 11 in. (21 cm by 28 cm) sheet of paper. The subject was instructed to circle all the "H's" as quickly as possible. The scores were: a) the time taken to complete the task and, b) the number of errors. Percent change scores from O1 to O2 were then calculated and evaluated for statistical significance.

2) Line Bisection, originally reported by Albert (1973) and refined to two equivelant, alternative formats (Schenkenberg, Bradford & Ajax, 1980), was given on 01, 02, and 03, with the first form administered on 01 and 03. Form two was given on 02. The test consisted of 20 lines (plus 1 extra line as an example) on a sheet of paper. The lines were spaced so that, when the sheet was turned upside down, an alternative form was created. Two scores were calculated: a) the time taken to complete the task and, b) the percent of deviation for marks placed either to left, right, or centre of the line. The formula for this was:

$$\text{Percent Deviation} = \frac{\text{Measured left half} - \text{True half}}{\text{True half}} \times 100$$

Scores were positive for marks to the right, and negative for marks to the left. An average was computed for each subject for the "Average Percent Deviation Score." Percent change scores from 01 to 02 were then calculated.

3) A task which required the circling of drawn boxes with a distinctive tail was administered on 01, 02, and 03. Four possible directions (right or left, with tail diagonally up or down) were presented on four separate sheets of paper. On each of the four sheets, there were 25 target boxes and 75

distractor boxes with tails drawn in wrong directions (see Appendix A). The scores were: a) the total correct number of boxes circled (maximum score = 100) and, b) the total time to complete all four sheets. From these scores, the percent change between 01 and 02 was determined.

4) Visual searching (Kimura, Barnett & Burkhart, 1981) was an adaptation of tests (Chedru, Leblanc & Lhermitte, 1973; and Teuber, Battersby & Bender, 1949) used to study visual search in patients with brain lesions. It consisted of 86 line drawings of common objects arranged over a vertical surface which was 56 cm wide and 51 cm high (see Appendix A). The subjects were asked to point to the identical match of a drawing presented on a card in the centre of the array. Twenty different cards were presented, 1 at a time, and the time taken to find the match was recorded. This task was administered to each subject on 01, 02, and 03. The scores were determined for each half of the Visual Search Board for: a) the number of items and, b) search times. These results allowed percent change scores from 01 to 02 for speed and the number of matched items in each visual field to be calculated.

5) Visual scanning (Fisk, Goodale, Burkhart, & Barnett, 1982) was given on 01, 02, and 03. This test was developed to assess visual scanning separately for the horizontal and vertical planes. It consisted of 10 lines arranged in parallel form on four 21.5 cm by 28 cm cards. Each line had a number of dots and dashes along its length (see Appendix

A): The patient was presented with four cards, one at a time. Two had a horizontal orientation, and two had a vertical orientation. Subjects were asked to scan five lines on each card in a specific direction - left to right, right to left, top to bottom, or bottom to top - and to report the number of dashes or dots on a specific line. The scores were: a) the number correct and, b) the average time it took to report the correct number of dots or dashes for both directions (horizontal and vertical) of scanning. Percent change scores from 01 to 02 for both horizontal and vertical scanning were then determined.

Procedure Summary

Subjects were selected for this study based on their files in the Division of Neuro-Ophthalmology and medical charts at Henry Ford Hospital. As subjects agreed to participate in the study, they were randomly assigned (without replacement) to either an Early treatment series or a Late treatment series, according to a random schedule devised by an independent graduate student, with the aid of a random number table. All subjects were given uniform treatment until the fourth experimental session, whereupon the Early series started to receive light threshold training, whereas the Late series continued in the control baseline phase (see Table 2). In the latter, subjects received brief (approximately 40 minutes) supportive, non-directive counselling and the repeated measures described above. The Late series of patients started light threshold treatment on experimental session 11 (see Table 2). Furthermore, all subjects received similar treatment on O1, O2, and O3. On O1, subjects received an initial interview, measures of general intelligence, handedness, language, repeated measures of motor, sensory, numeral reading speed and accuracy, auto perimetry, Goldmann Perimetry, standardized reading tests, and measures thought to assess "everyday" visual abilities. On O2, the interview, general intelligence, handedness, and language testing were not repeated; but all other measures given during O1 were repeated. On O3, the tests given on O2 were repeated, with the addition of a final interview. The approximate time required for these three observation days varied from three to six hours, depending on how quickly the individual subject progressed through the testing. The entire 17 sessions were typically completed within two months; however, one subject required more time between sessions during Christmas holidays, and, thus, needed three months.

CHAPTER THREE

RESULTS

The use of statistical significance tests is controversial in the multiple baseline across cases method (Gianutsos & Gianutsos, 1979; Hersen & Barlow, 1976; Kazdin, 1981, 1982). The recommended method (Gianutsos & Gianutsos, 1979; Kazdin, 1976) of analysis is a visual inspection of the treatment effects on repeated measures, compared to baseline levels. For this method, the definition of "clinical" significance is that treatment is effective in improving each subject's scores to the point that it is apparent by visually inspecting the level of performance during the baseline and treatment sessions.

Gianutsos and Gianutsos (in press) point out that visual inspection of experimental results is a common manner of analyzing single-case designs, and that, historically, it is linked to operant methodology. They appeal to the authority of Skinner's classic (1950) article on learning theory, where he suggested that, if intervention effects are not effective enough to be convincing by visual inspection, then they are not likely to be important. However, a method of statistical confirmation of possible treatment effects, which does not preclude visual inspection, has been suggested by White (1972) and iterated by Kazdin (1976), as a technique useful in describing change in individuals' behaviours over time. This is known as the "Split Middle" procedure, and was used, with a slight modification, in a recent study of memory rehabilitation in a brain-injured patient (Gianutsos, 1981).

Gianutsos and Gianutsos (in press) strongly advocated this method for the statistical confirmation of treatment effects in multiple baseline across cases studies, and provided a good discussion, with a step-by-step example, of how they applied it. They referred to it as the "projected regression line technique", because the technique utilized the baseline data to project the best fitting regression line (or curve) through the experimental sessions. The refinement added by Gianutsos (1981) was the use of a nonlinear first-order hyperbolic function, or best fitting curve, rather than a straight regression line. This was based on the a priori reasoning that an initial increase in baseline data, due to "initial adjustment", followed by a levelling off, was expected. The equation for this hyperbolic function can be expressed as:

$$Y = b\,(1/X) + a$$

Where "Y" becomes the datum point on the best fitting projected curve, "X" is the session number, and a conventional linear regression of "Y" and "(1/X)" yields the coefficients "a" and "b" (for (1/X) values used in this dissertation see Appendix B).

From this, one can observe that the coefficients themselves contain useful information. For example, the asymptotic value of the function (the value of "Y" as "X" increases) is limited to the value for "a" and represents the most extreme value "Y" can have. On the other hand, "b" represents the difference between the starting point and the limiting value "a". In other words, "a" represents the maximum intercept value, and "b" equals the slope of the best fitting curve. Finally, the value "b" will indicate a rising curve, projected from baseline, if it is a negative value; it will indicate a decreasing curve if it is a positive value.

To statistically evaluate the results of a multiple baseline study one considers the number of treatment data points that fall above (or below, depending upon the direction indicating improvement) the projected curve. The null hypothesis is that the treatment has no effect. If this is true, then the projected curve (or celeration line) from the baseline phase should be a valid estimate of the treatment data points. Assuming this, the projected curve should "split" the treatment phase data points so that 50% of them fall above, and 50% of them fall below the best fitting curve projected from baseline through the treatment phase.

Using a binomial test to evaluate the reliability of the difference between the projected and actual scores, one assumes the probability of 50% (i.e., p=.5) for the null hypothesis. The binomial applied to the split middle slope would then be the probability of attaining "r" number of data points above (or below) the projected curve. This can be formulated as:

$$f\{r\} = \binom{n}{r} p^{r} q^{n-r}.$$

Or more simply:

$$\binom{n}{r} p^{n}$$

where "n" equals the number of total data points in the treatment phase; "r" equals the number of data points above (or below) the projected curve; "p" and "q" equal 0.50 by definition of the "split middle." Thus the obtained "p" value will equal the exact probability of "n" data points appearing above (or below) the curve given the null hypothesis (Kazdin, 1976).

A table is provided for the reader at the end of this dissertation (Appendix B) which lists the probability levels for the possible outcomes encountered in this study. For example, the Early treatment group obtained 14 treatment data points on the repeating measures, and the Late treatment group received 7 treatment data points on the repeating measures. Since a priori reasoning indicates that patients will improve on the various measures, one-tail tests of significance were employed.

The results for light target detection, sensory, motor and the repeated numeral reading scores were analyzed with both visual inspection and the "split middle" technique described above, using the binomial test for significance levels. In Appendix C the results for these repeating measures have been grouped so that each individual subject's results, including baseline performance, are on one page for ease of interpretation.

The analysis of the three standardized reading tests, Goldmann Perimetery, and the five measures of "everyday" vision employed visual inspection (of tabled and graphed scores) and a group comparison (Early vs. Late) approach. An absolute comparability of performance levels was questionable in these randomly assigned independent treatment groups. This was due to initial differences between the groups, documented in Table 1 (p.29), prior to training. Also, the assumptions required for traditional inferential statistics were suspect. Thus, a nonparametric statistic for unrelated samples (Mann-Whitney U test) was used to evaluate both groups on percent change scores from 01 to 02.

First, the data on target detection are presented allowing an evaluation of hypothesis one.

E1: The results on target detection during repeated measures on auto perimetry are presented in Figures 1 and 2, showing the results for the left visual field and right visual field, respectively. The first thing apparent is that she successfully detected roughly 80% of the targets presented in her left visual field and 90% in her right visual field throughout the 17 sessions. The left visual field was selected for light threshold training (along the 105° meridian in each eye). By visual inspection and the binomial split middle test for significance (left visual field $=p<.999$; right visual field $=p<.61$), one can observe that, for E1, there has been no treatment effect for target detection. Out of the 28 data points during the treatment sessions of both visual fields, only 10 fell above the curve projected from baseline.

Insert Figures 1 & 2 (p. 60)

E2: The results on target detection for E2 are presented in Figures 3 and 4 for the left and right visual fields, respectively. From Figure 3 one can observe that E2 detected roughly 90% of the targets presented to his left visual field; Figure 4 shows that he detected between 35 to 50% of the targets in the right visual field throughout the 17 sessions. Light threshold training was conducted in the right visual field (along the 45° meridian in each eye). Both the binomial test for significance (left visual field $=p<.97$; right visual field $=p<.91$) and visual inspection revealed no treatment effect for target detection. Out of 28 data points during the treatment sessions, only 9 points

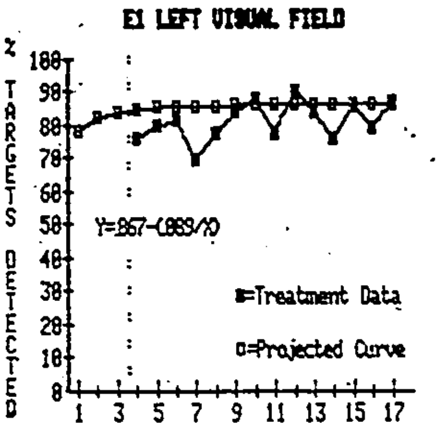

Figure 1. Graph shows treatment data points compared to baseline projectd curve.

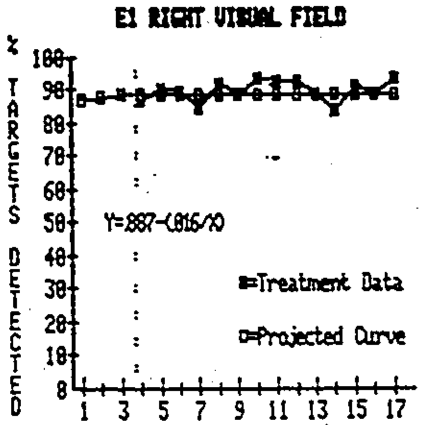

Figure 2. Graph shows treatment data compared to baseline projected curve.

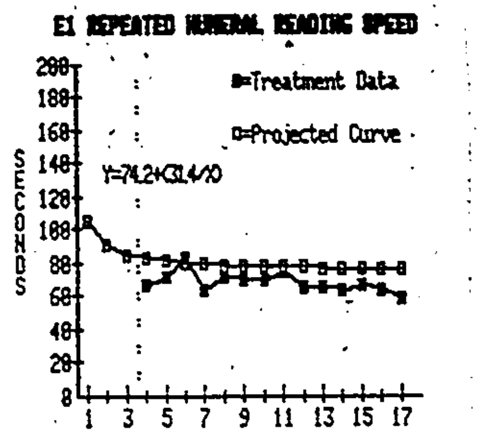

Figure 55. Graph shows treatment data compared to baseline projected curve.

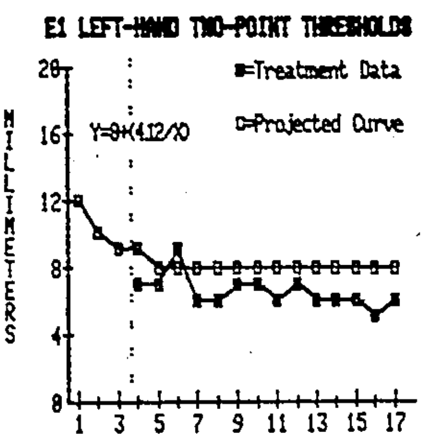

Figure 19. Graph shows treatment data compared to baseline projected curve.

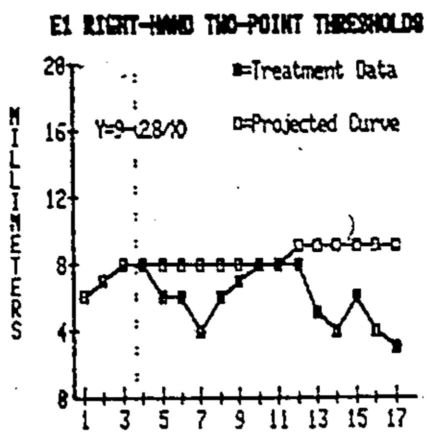

Figure 28. Graph shows treatment data compared to baseline projected curve.

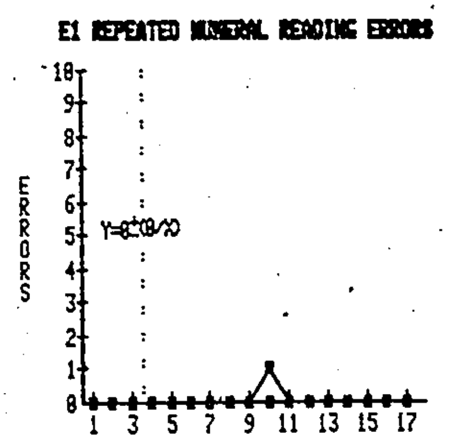

Figure 56. Graph shows treatment data not significantly different from curve.

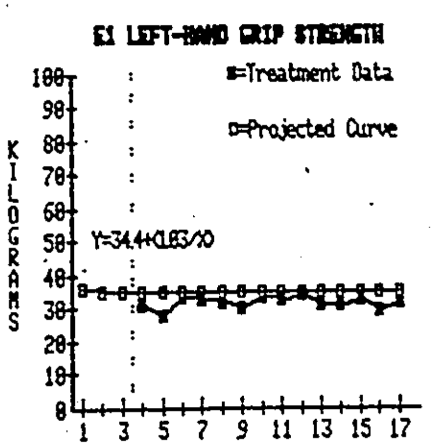

Figure 21. Graph shows treatment data compared to baseline projected curve.

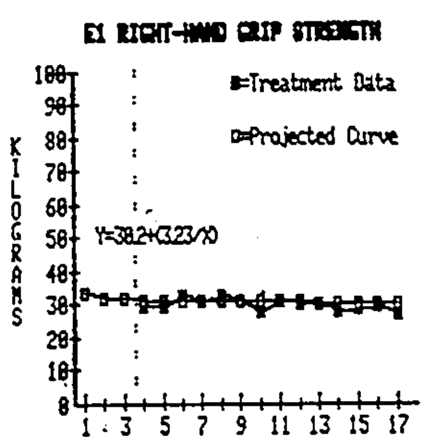

Figure 22. Graph shows treatment data compared to baseline projected curve.

fell above the curve projected from the three baseline sessions.

Insert Figures 3 & 4 (p. 62)

E3: The results for E3 are presented in Figures 5 and 6, which show the results for both the left and right visual field, respectively. Target detection improved from roughly 70% to 95% in the left visual field and from 4% to about 30% in the right visual field across the 17 sessions.

The right visual field was exposed to light threshold training (along the 45° meridian in each eye). Both visual inspection of the data and the binomial test revealed a significant improvement (left visual field $=p<.001$; right visual field $=p<.0001$) of target detection on the auto perimeter. Of the 28 treatment data points (14 for each visual field), 27 fell above the curve projected from the baseline sessions.

Insert Figures 5 & 6 (p. 63)

E4: The results on target detection for E4 are presented in Figures 7 and 8 for both the left and right visual fields, respectively. In Figure 7, one can see that target detection improved from an initial 16% to roughly 30% in the left visual field across the 17 sessions. In Figure 8, initially 80% of the targets were detected, which improved

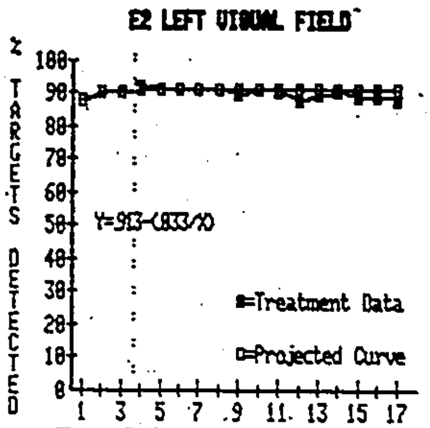

Figure 3. Graph shows treatment data compared to baseline projected curve.

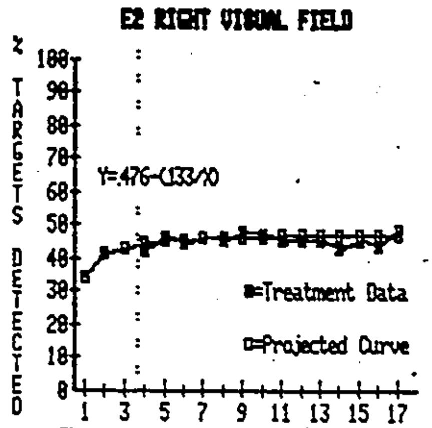

Figure 4. Graph shows treatment data compared to baseline projected curve.

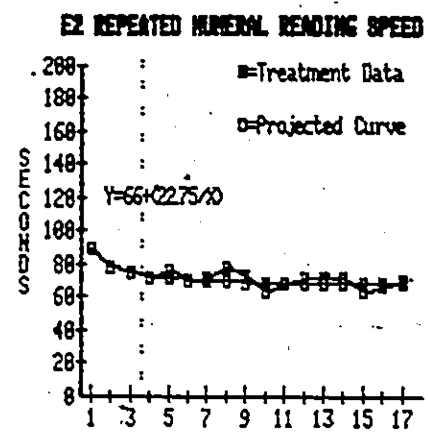

Figure 57. Graph shows treatment data compared to baseline projected curve.

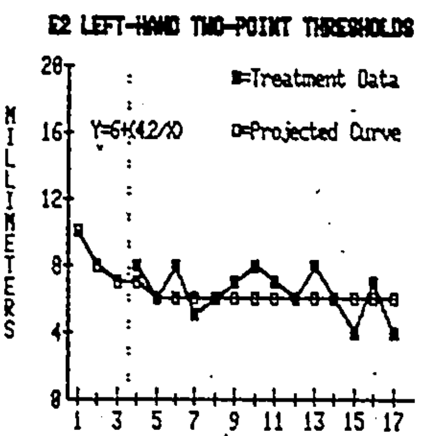

Figure 23. Graph shows treatment data compared to baseline projected curve.

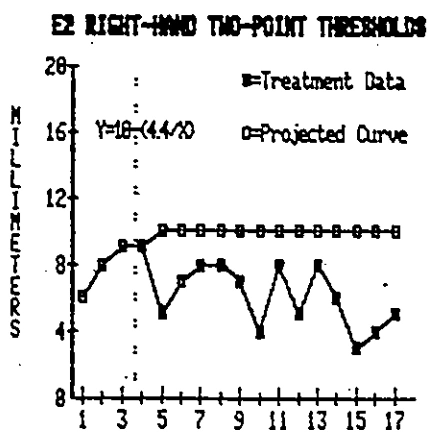

Figure 24. Graph shows treatment data compared to baseline projected curve.

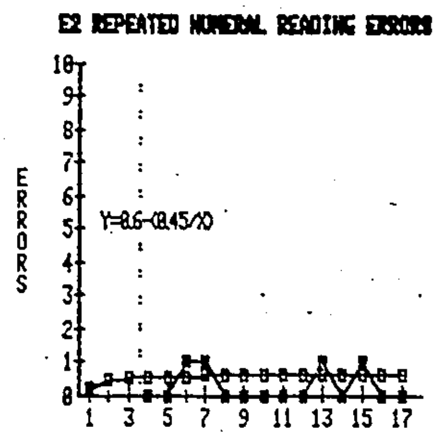

Figure 58. Graph shows treatment data not significantly different from curve.

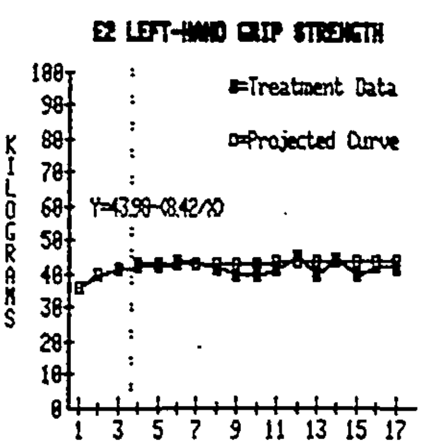

Figure 25. Graph shows treatment data compared to baseline projected curve.

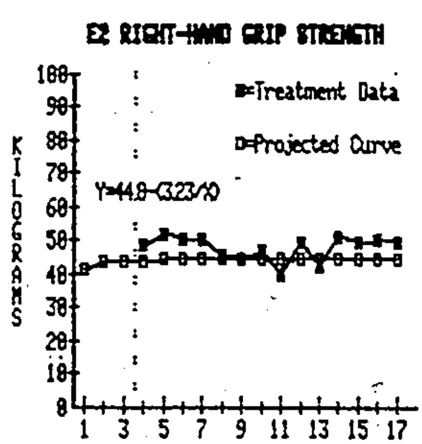

Figure 26. Graph shows treatment data compared to baseline projected curve.

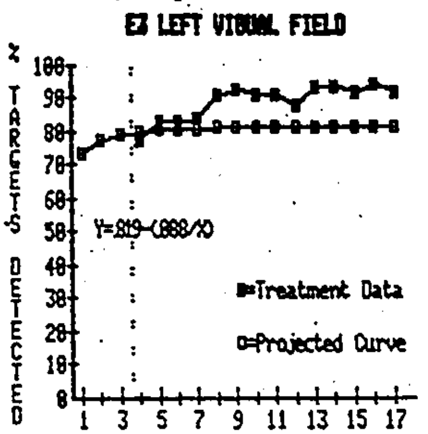

Figure 5. Graph shows treatment data compared to baseline projected curve.

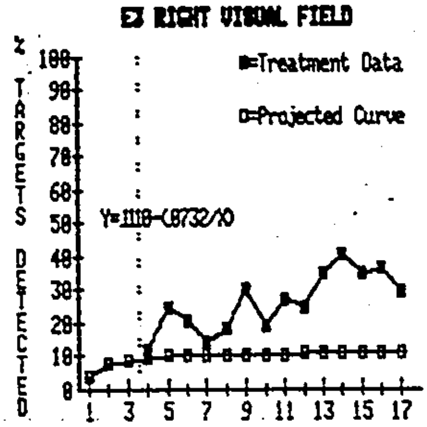

Figure 6. Graph shows treatment data compared to baseline projected curve.

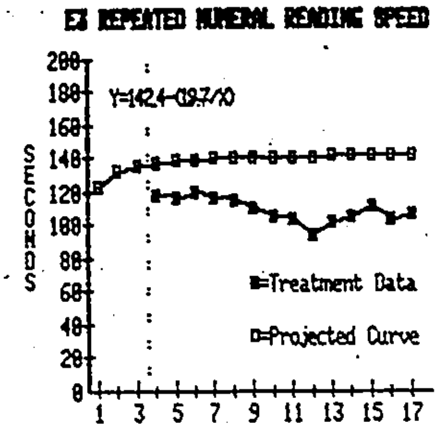

Figure 59. Graph shows treatment data compared to baseline projected curve.

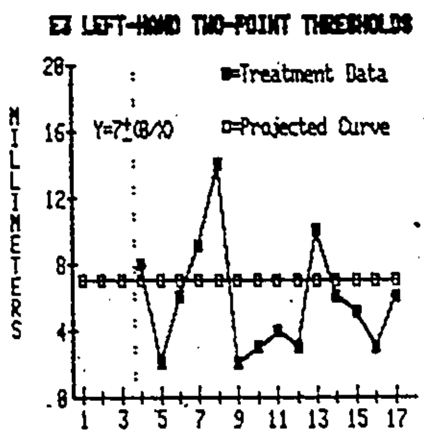

Figure 27. Graph shows treatment data compared to baseline projected curve.

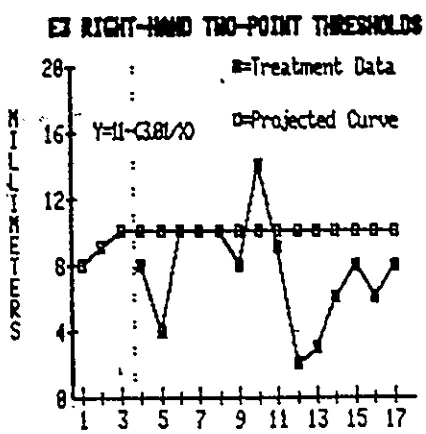

Figure 28. Graph shows treatment data compared to baseline projected curve.

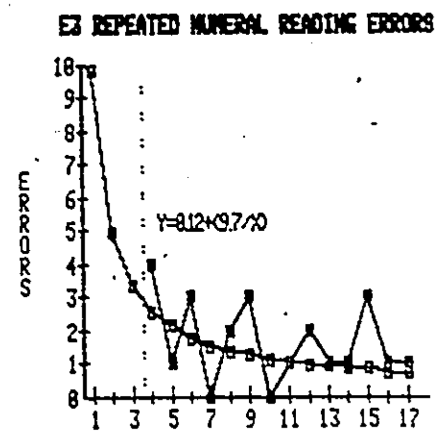

Figure 60. Graph shows treatment data compared to baseline projected curve.

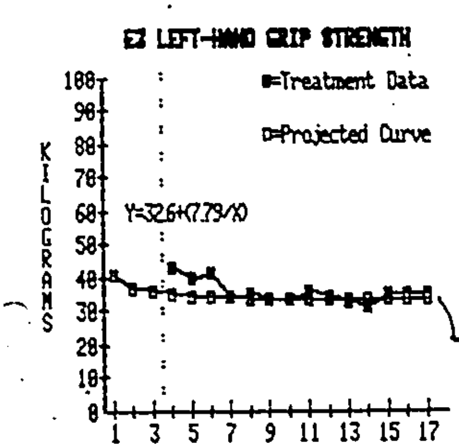

Figure 29. Graph shows treatment data compared to baseline projected curve.

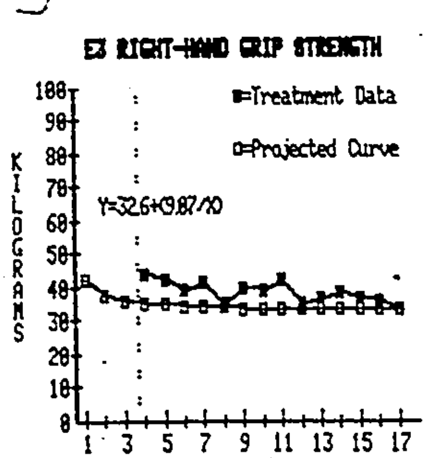

Figure 30. Graph shows treatment data compared to baseline projected curve.

to roughly 95% over the course of the study. The left visual field received the light threshold training (along the 145° meridian in each eye). Figures 7 and 8 indicated a significant effect for treatment in both visual fields by visual inspection and the Binomial test for significance (left visual field $=p<.0001$; right visual field $=p<.0001$). Out of the 28 treatment data points, for both visual fields combined, all were above the curve projected from the baseline sessions.

Insert Figures 7 & 8 (p. 65)

L1: The results for L1 are presented in Figures 9 and 10 for the left and right visual fields, respectively. In Figure 9, it was observed that initially roughly 30% of the targets in the left visual field were detected. By the end of the study, this changed to about 45%. In the right visual field, about 75% were initially detected. This improved to about 83% after 17 sessions. The left visual field received the light threshold training (along the 225° meridian in only the right eye). In this subject, it should be recalled that only the right eye was trained, due to an early left eye injury from a BB gun. By visual inspection of Figures 9 and 10 it appeared that training improved the number of lights detected in both visual fields. When evaluated with the binomial test, the improvement observed in both visual fields approached significance ($p<.06$). Out of the total of

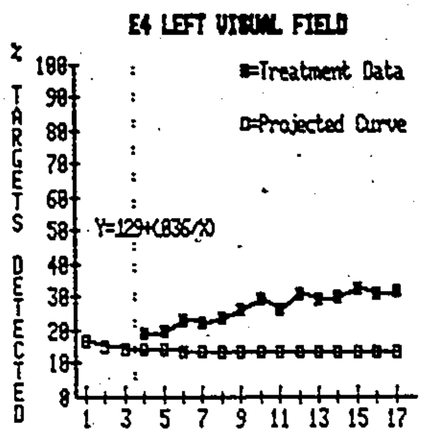

Figure 7. Graph shows treatment data compared to baseline projected curve.

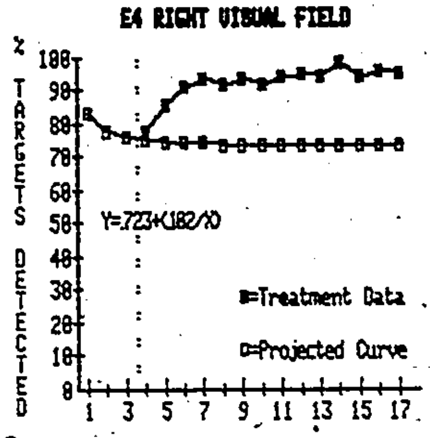

Figure 8. Graph shows treatment data compared to baseline projected curve.

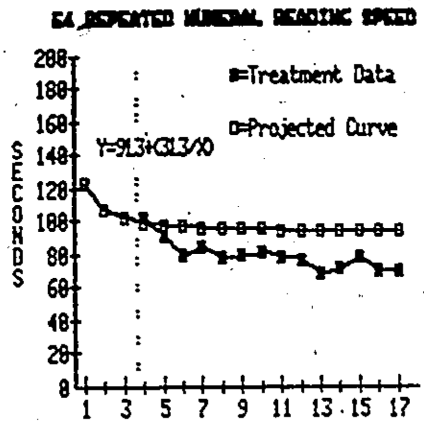

Figure 61. Graph shows treatment data compared to baseline projected curve.

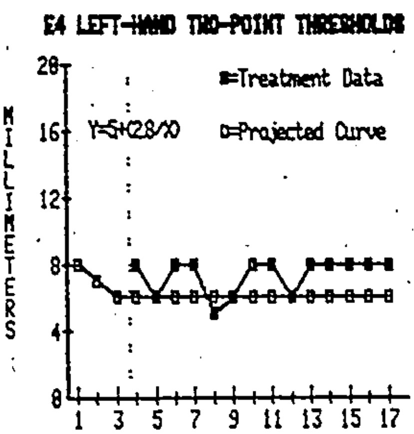

Figure 31. Graph shows treatment data compared to baseline projected curve.

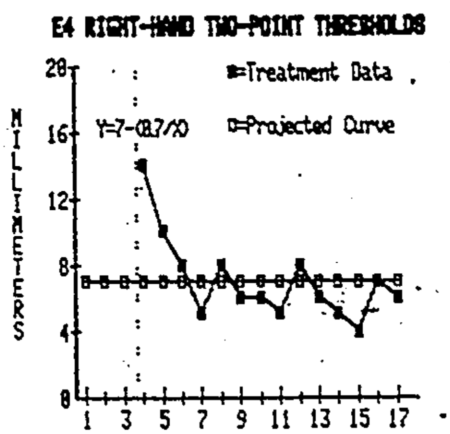

Figure 32. Graph shows treatment data compared to baseline projected curve.

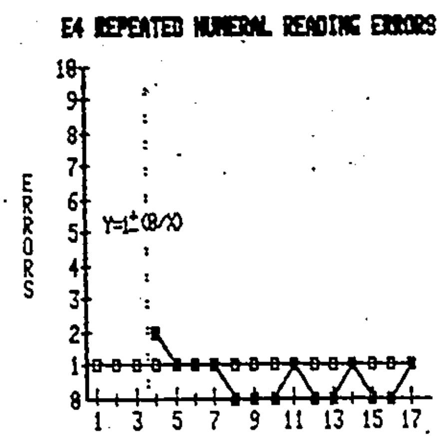

Figure 62. Graph shows treatment data compared to baseline projected curve.

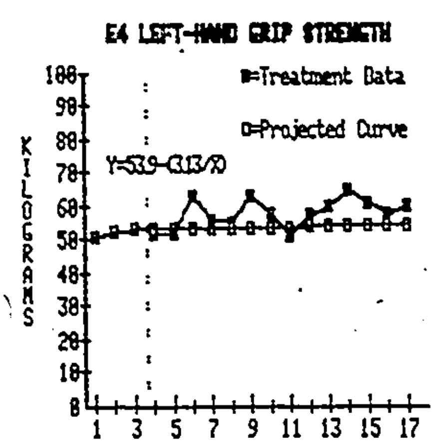

Figure 33. Graph shows treatment data compared to baseline projected curve.

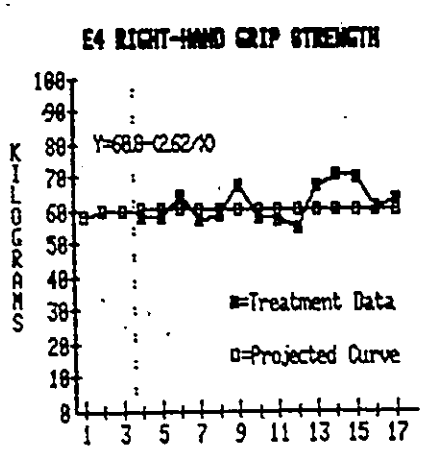

Figure 34. Graph shows treatment data compared to baseline projected curve.

14 treatment data points, 12 were above the curve projected from baseline data.

Insert Figures 9 & 10 (p. 67)

L2: Results for L2 are presented in Figures 11 and 12 and show the results for the left and right visual fields, respectively. Initially, 70% of the targets presented to the left visual field were detected. This increased to roughly 85% by the last session. In the right visual field, initially 95% of the targets were detected. This increased to about 100% by the last experimental session. The left visual field received the light threshold training (along the 225° meridian for both eyes). By visual inspection of the data points, there appeared to be no effect from treatment. In Figure 11, the binomial test for the left visual field also indicated no significant effect ($p<.50$). However, the data for the right visual field, presented in Figure 12, approached significance ($p<.06$). This showed the importance of using both visual inspection and a statistical evaluation of the data. The binomial test did not reveal the magnitude of improvement. This was best assessed by visual inspection. Of the total of 14 treatment data points, 10 were above the projected baseline curve. When each field was evaluated separately, the left field revealed that 4 of 7 points were above the curve. Of the 7 right visual field data points, 6 were above the projected curve.

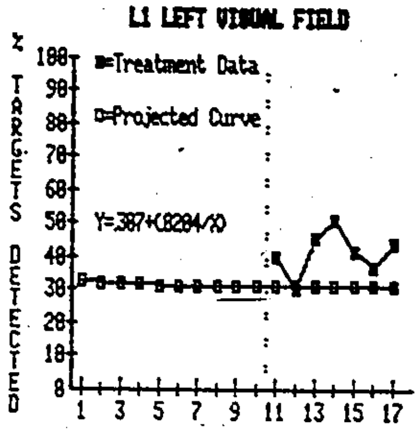

Figure 9. Graph shows treatment data compared to baseline projected curve.

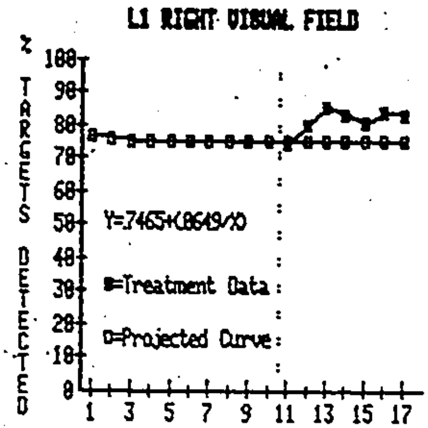

Figure 18. Graph shows treatment data compared to baseline projected curve.

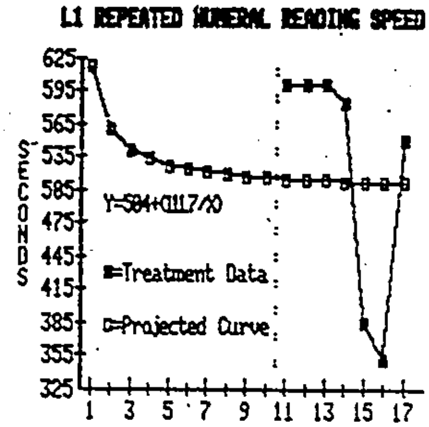

Figure 63. Graph shows treatment data compared to baseline projected curve.

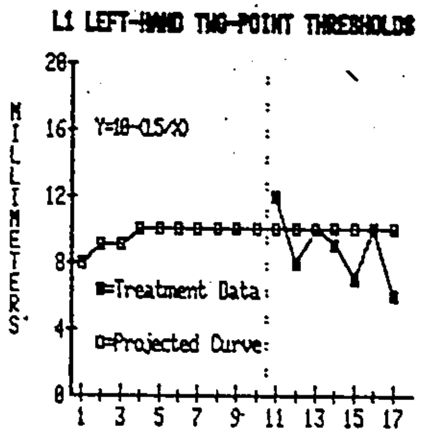

Figure 35. Graph shows treatment data compared to baseline projected curve.

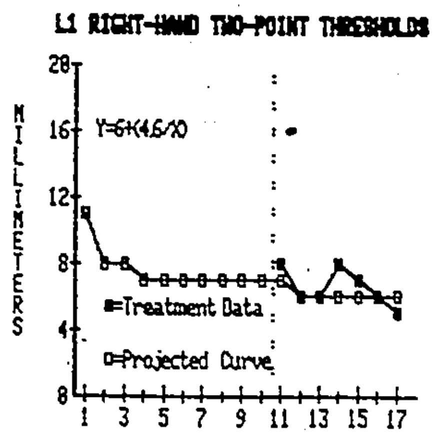

Figure 36. Graph shows treatment data compared to baseline projected curve.

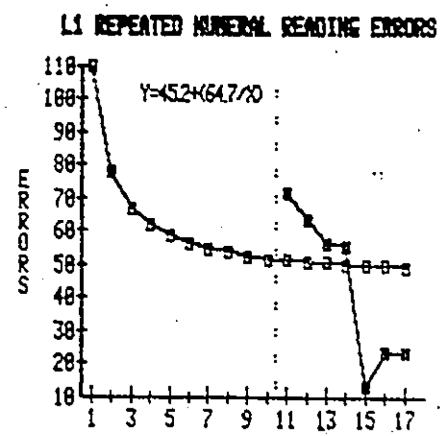

Figure 64. Graph shows treatment data compared to baseline projected curve.

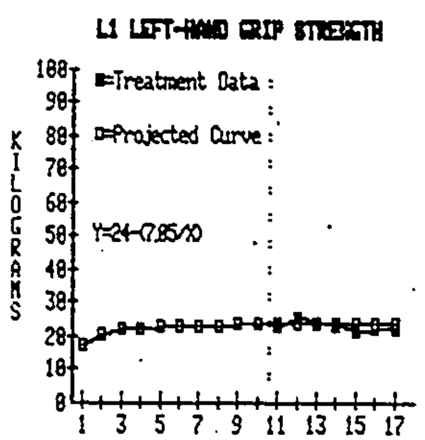

Figure 37. Graph shows treatment data compared to the baseline projected curve.

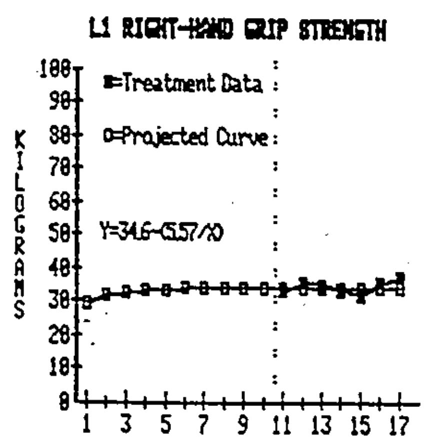

Figure 38. Graph shows treatment data compared to baseline projected curve.

Insert Figures 11 & 12 (p. 69)

L3: The results of L3's target detection performance on the auto perimeter is presented in Figures 13 and 14, showing the left and right visual field, respectively. In the left visual field, 4% of the targets were initially detected. By the end of the study, this improved to roughly 20% target detection. In the right visual field, an initial 70% target detection rate occurred, which improved to roughly 95% by the end of the 17 sessions. The left visual field was selected for light threshold treatment (along the 135° meridian in both eyes). By visual inspection it appeared that the treatment had an effect for both visual fields. However, the binomial test for the left visual field only approached significance ($p<.06$) whereas the right visual field was significant ($p<.01$). Of the total of 14 treatment data points for both fields together, 13 were above the curve projected from the baseline.

Insert Figures 13 & 14 (p. 70)

L4: Target detection results for L4 are presented in Figures 15 and 16 for the left and right visual fields, respectively. In the left visual field, L4 initially detected roughly 90% of the targets, and, after treatment, this increased to almost 100% of the light targets. In the

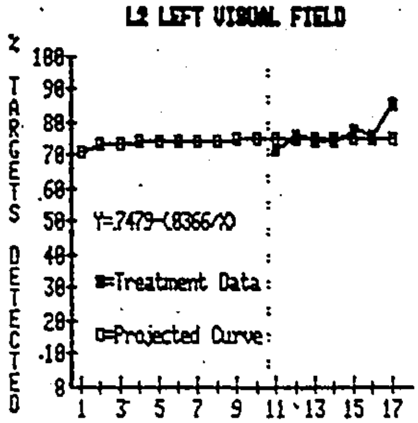

Figure 11. Graph shows treatment data compared to baseline projected curve.

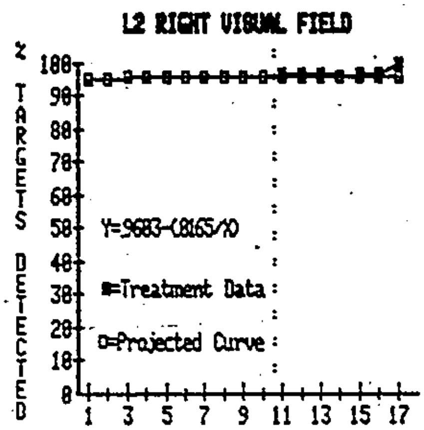

Figure 12. Graph shows treatment data compared to baseline projected curve.

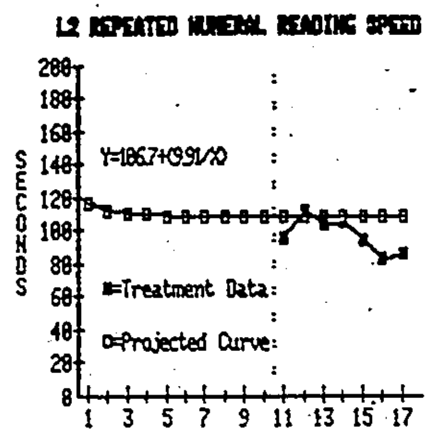

Figure 65. Graph shows treatment data compared to baseline projected curve.

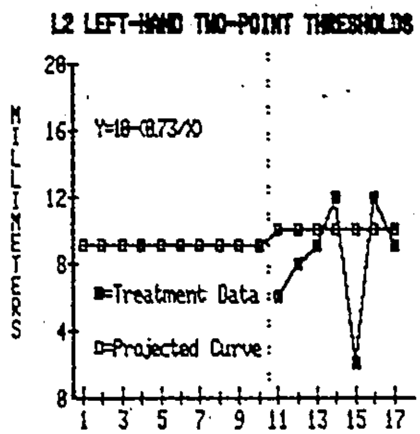

Figure 39. Graph shows treatment data compared to baseline projected curve.

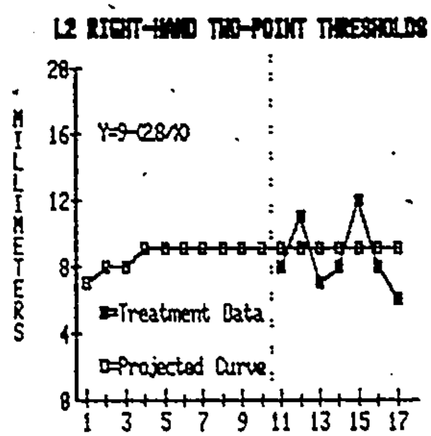

Figure 48. Graph shows treatment data compared to baseline projected curve.

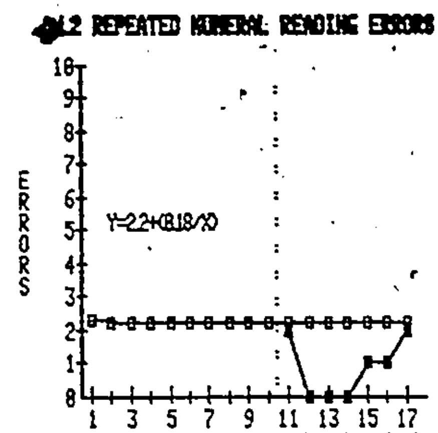

Figure 66. Graph shows treatment data compared to baseline projected curve.

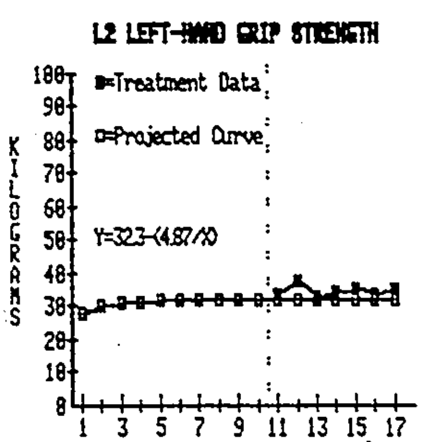

Figure 41. Graph shows treatment data compared to baseline projected curve.

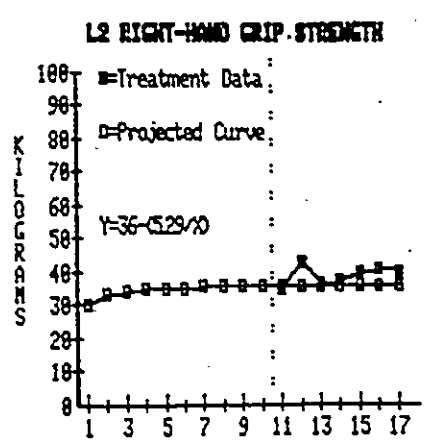

Figure 42. Graph shows treatment data compared to baseline projected curve.

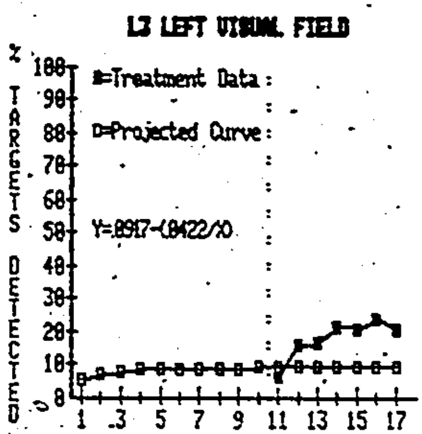

Figure 13. Graph shows treatment data compared to baseline projected curve.

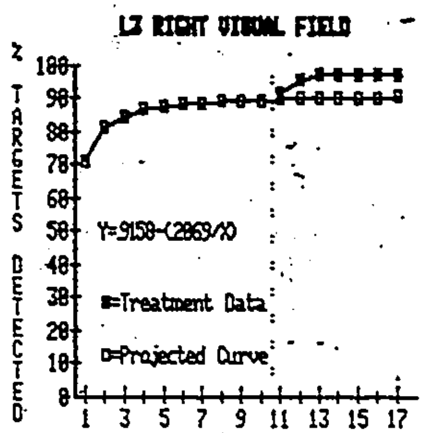

Figure 14. Graph shows treatment data compared to baseline projected curve.

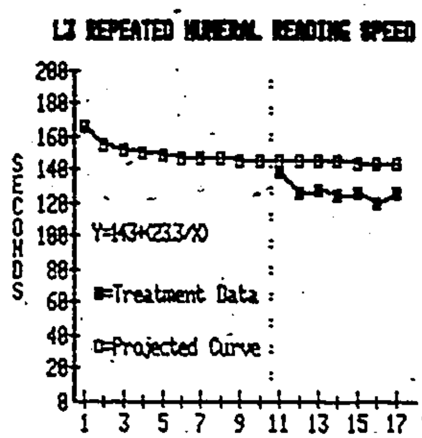

Figure 67. Graph shows treatment data compared to baseline projected curve.

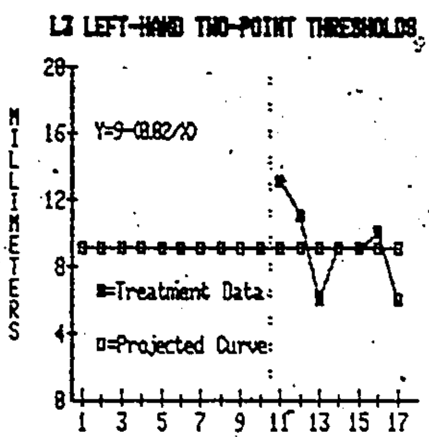

Figure 43. Graph shows treatment data compared to baseline projected curve.

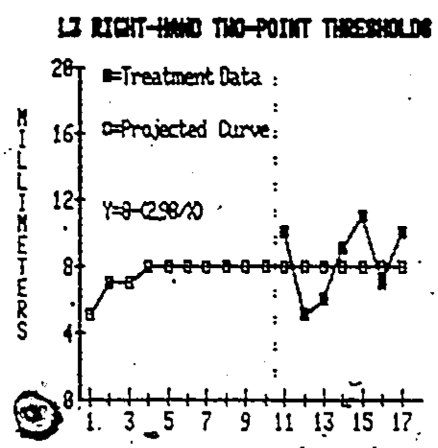

Figure 44. Graph shows treatment data compared to baseline projected curve.

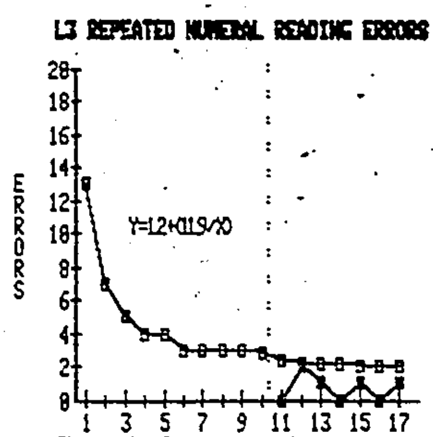

Figure 68. Graph shows treatment data compared to baseline projected curve.

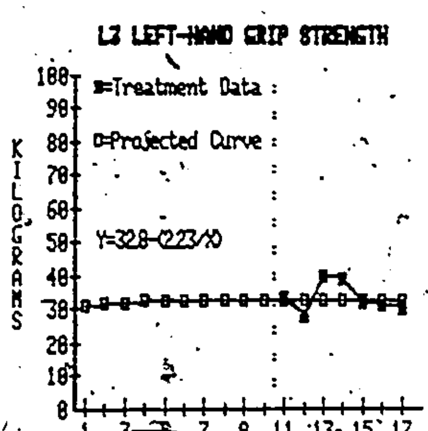

Figure 45. Graph shows treatment data compared to baseline projected curve.

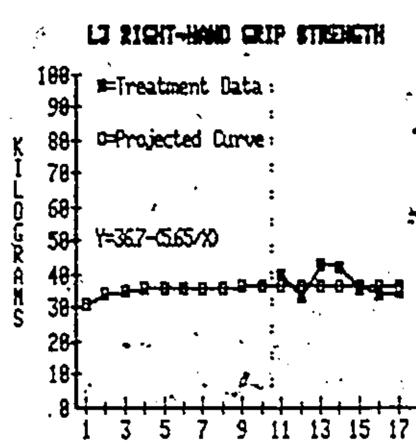

Figure 46. Graph shows treatment data compared to baseline projected curve.

right visual field, the increase was from an initial 25% to about 35% of the light targets detected, after treatment sessions. The right visual field was selected for light threshold training (along the 45° meridian in each eye). By visual inspection, it appeared that the increase in the light target detection was associated with the initiation of the treatment and that the improvement seen initially continued throughout the rest of the study. The binomial test indicated that the left visual field improvement approached significance (p<.06), whereas the increase in the right visual field was significant (p<.01). Of the total 14 treatment data points, 13 were above the baseline-projected curve.

Insert Figures 15 & 16 (p. 72)

L5: The target detection results for L5 are presented in Figures 17 and 18, and represent the left and right visual field, respectively. The left visual field graph illustrated that, initially, 90% of the targets were detected, which improved to almost 100%. The right visual field showed a similar pattern of initially beginning with 90% detection rate, which increased to roughly 100% at the end of the treatment sessions. The right visual field was selected for training and the 315° meridian was selected in each eye because this radial transected a paracentral scotoma. By visual inspection, it appeared that the treatment sessions

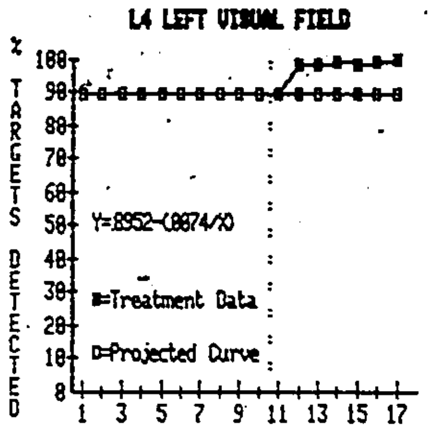

Figure 15. Graph shows treatment data compared to baseline projected curve.

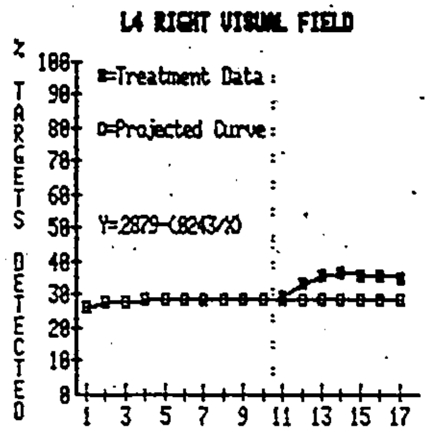

Figure 16. Graph shows treatment data compared to baseline projectyed curve.

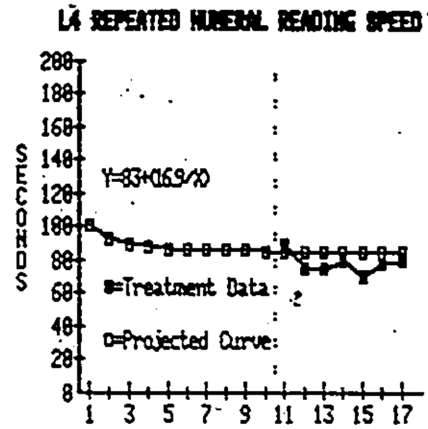

Figure 69. Graph shows treatment data compared to baseline projected curve.

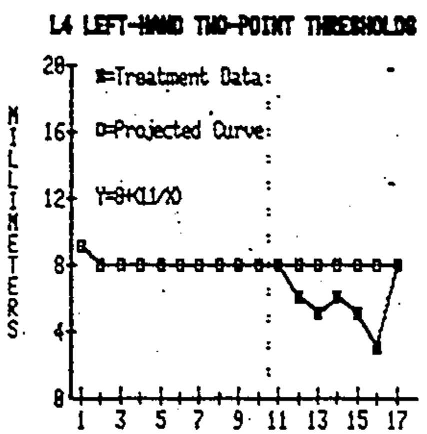

Figure 47. Graph shows treatment data compared to baseline projected curve.

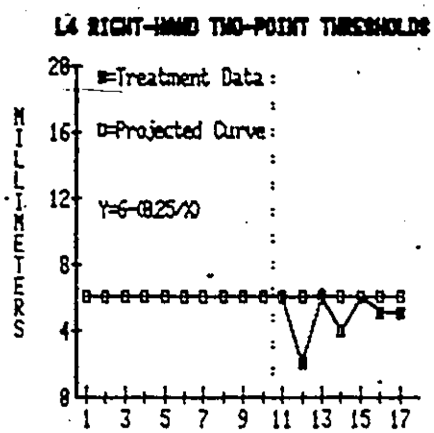

Figure 48. Graph shows treatment data compared to baseline projected curve.

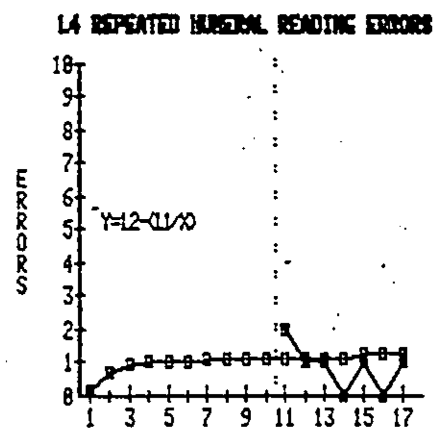

Figure 78. Graph shows treatment data compared to baseline projected curve.

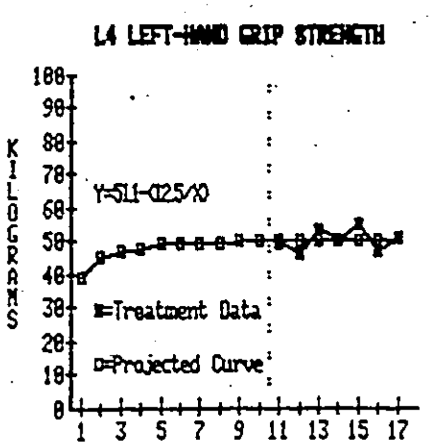

Figure 49. Graph shows treatment data compared to baseline projected curve.

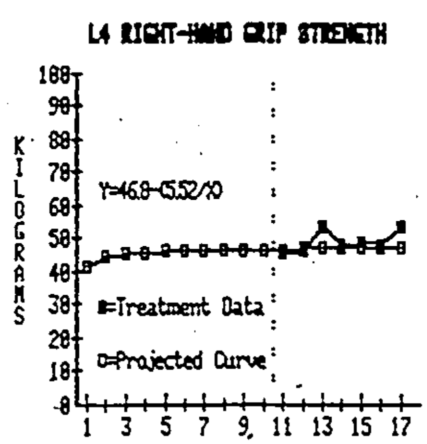

Figure 58. Graph shows treatment data compared to baseline projected curve.

increased the detection of light targets. However, the binomial test for significance suggested that this only approached significance for both visual fields ($p<.06$). Of the total of 14 treatment data points across both visual fields, 12 were above the curve projected from the baseline data.

Insert Figures 17 & 18 (p. 74)

In summary, for the detection of light targets presented by the auto perimeter, it appeared that, of the 4 subjects who received the Early training, 2 showed no treatment effect and 2 did. Furthermore, 1 of the 2 that did not show an effect was performing, throughout the study, in the 90% range in both visual fields. Of the 5 subjects who received Late treatment, 4 appeared, upon visual inspection, to improve with treatment. However, with the "split middle" binomial test for significance, 2 showed improvement at the $p<.01$ level in at least one visual field, and 2 others approached this, with $p<.06$ for both visual fields. Thus, of the 9 subjects in this study, 6 showed improved target detection scores in at least one visual field with light threshold training. Of the total number of treatment session data points (total=182) across all subjects, 74% of these points (or 134) fell above the level predicted by the various baseline projected curves. This suggested that light

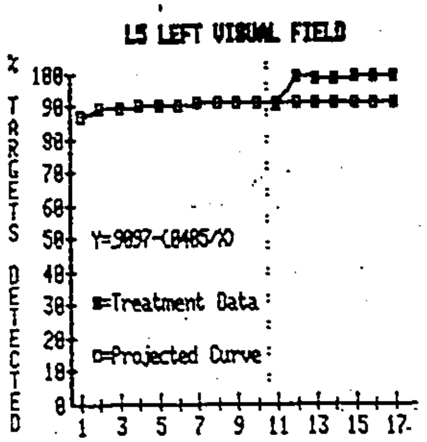

Figure 17. Graph shows treatment data compared to baseline projected curve.

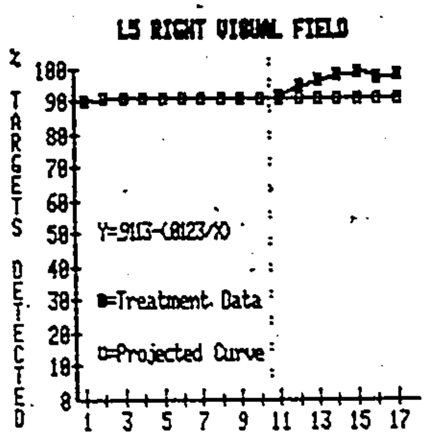

Figure 18. Graph shows treatment data compared to baseline projected curve.

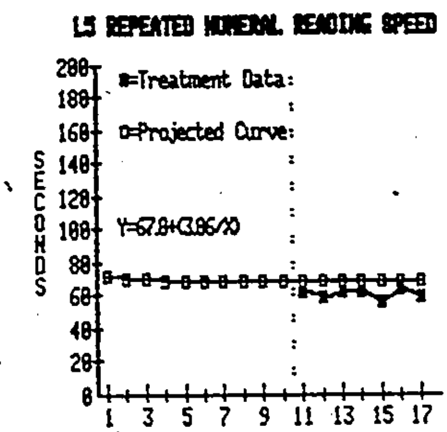

Figure 71. Graph shows treatment data compared to baseline projected curve.

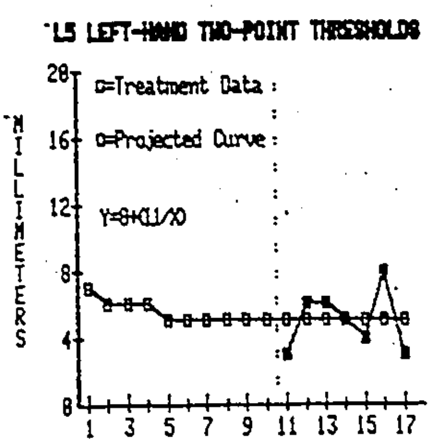

Figure 51. Graph shows treatment data compared to baseline projected curve.

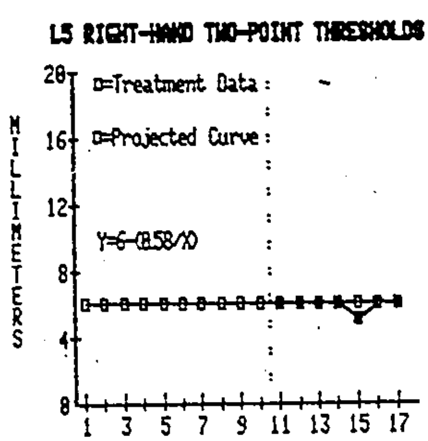

Figure 52. Graph shows treatment data compared to baseline projected curve.

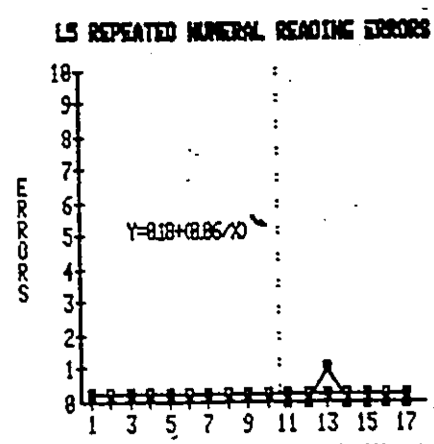

Figure 72. Graph shows no significant difference between treatment and baseline projected curve data.

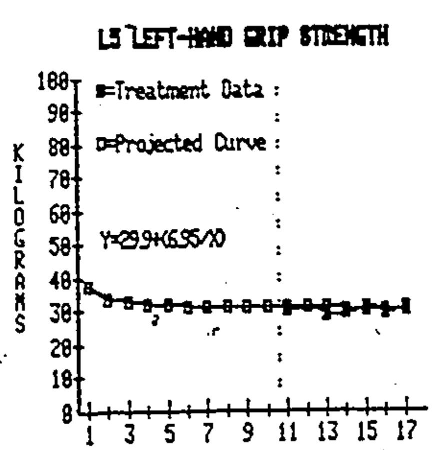

Figure 53. Graph shows treatment data compared to baseline projected curve.

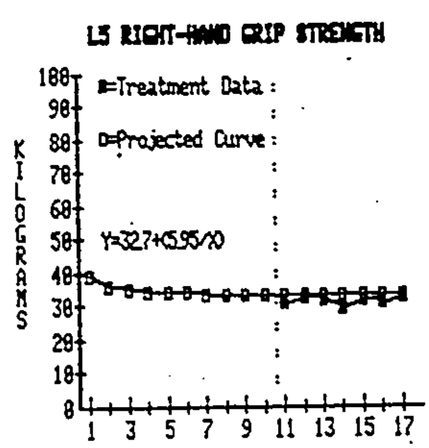

Figure 54. Graph shows treatment data compared to baseline projected curve.

threshold treatment was effective in improving the detection of light targets in patients with posterior brain lesions.

We now turn to consider the results for the sensory and motor repeated testing to evaluate the second hypothesis.

E1: The results for the left- and right-hand two-point sensory thresholds for E1 are presented in Figures 19 and 20, respectively. The left-hand score was initially 12 mm; this improved over the course of the study to about 6 mm. The right hand showed similar improvement, starting at 6 mm and going to 3 mm. Both visual inspection and binomial testing indicated that E1 improved significantly (left hand $=p<.001$; right hand $=p<.03$) during the treatment sessions (see Figures 19 and 20) on these tests of sensory function. Of the 28 treatment data points collected from both hands, 24 were below (the direction of improvement for this measure) the curve projected from the baseline measures.

Insert Figures 19 and 20 (p. 60)

The results for E1's repeated measures of left- and right-hand grip strength are presented in Figures 21 and 22, respectively. This left-handed subject initially had a grip strength of roughly 35 kg for both hands, and this stayed fairly constant throughout the study. Both visual inspection and binomial testing showed no significant treatment effect (left $=p<.999$; right $=p<.97$) or improvement during the experimental sessions. Of the 28 treatment data points, only 4 were above the curve projected from baseline measures.

Insert Figures 21 and 22 (p. 60)

E2: The two-point sensory thresholds for E2's left and right hand are presented in Figures 23 and 24, respectively. On the left hand, the two-point threshold was initially 10 mm, which reduced to roughly 4 mm by the final session. The right hand showed an initial two-point score of 6 mm which increased through the rest of the baseline measures. This led to a rising projected curve through the treatment sessions. The actual treatment data obtained were consistently lower than this projection, with the final measure being 5 mm. Visual inspection of the graphs suggested that there was no improvement for the left-hand thresholds but significant improvement for the right.
This was also supported by the binomial test for significance (left $=p<.999$; right $=p<.001$). However, in examination of the raw data for the right hand, together with the overall variability of performance on this task, there was some question that improvement actually occurred; it is possible the results simply represented measurement error. Of the 28 treatment data points, for both hands together, 16 were below the projected curve from baseline.

Insert Figures 23 and 24 (p. 62)

The results for E2's dynamometer scores are presented in Figures 25 and 26. This subject was right-handed, and consistently performed slightly better with this dominant hand. He initially obtained a left-hand grip strength of 35.5 kg. The final score was 41.5 kg during the last session. On the right, he initially obtained a measurement of 40.5 kg, which improved to 49 kg on the last session. Visual inspection of the graphed data indicated no real change for the left hand, with perhaps some improvement for the right. The binomial test for significance also indicated that there was no improvement for the left hand ($p<.79$); however, there was a significant effect ($p<.03$) for the right hand. Of the 28 treatment data points, for both hands together, 17 were above the curve projected from the baseline data.

Insert Figures 25 and 26 (p.62)

E3: The results for left- and right-hand two-point thresholds are presented in Figures 27 and 28, respectively. Initially, the left-hand two-point threshold was 7 mm, and the final session measure was 6 mm. For the right hand, he obtained a score of 8 mm on both the first and last session measures. Visual inspection revealed considerable variability in the scores and binomial testing suggested no improvement during the treatment sessions for either hand (left $=p<.09$; right $=p<.09$). Of the 28 treatment data points, 20 were below (in the improved direction) the curves projected from baseline.

Insert Figures 27 and 28 (p. 63)

The dynamometer scores for E3's left and right hand are presented in Figures 29 and 30, respectively. This right-handed subject initially had a left-hand grip strength of 41 kg; and on the final assessment, obtained a measurement of 34 kg. The right-hand grip strength initially was 43 kg and his final score on the right was 33 kg. Visual inspection showed that, for both hands, this subject gradually had weaker grip strength scores throughout the study. No other evidence of neurological deterioration was evident. There was no apparent explanation for this. Because the decrease was gradual, the binomial test revealed a significant result for both the left ($p<.03$) and right ($p<.001$) hands. Of the 28 treatment data points, 24 were above the curves projected from baseline data.

Insert Figures 29 and 30 (p. 63)

E4: The results for left- and right-hand two-point sensory thresholds are presented in Figures 31 and 32, respectively. The left-hand score was 8 mm at the begining of the study, and was 8 mm on the final measurement. Initially, the right-hand threshold was 7 mm. The measurement for the final session was 6 mm. Both visual inspection and the binomial test for the left ($p<.999$) and right ($p<.40$) showed no improvement throughout the experiment on two-point thresholds. Of the 28 treatment data points, only 9 were improved from the curve projected from baseline.

Insert Figures 31 and 32 (p.65)

The results for E4's grip strength scores are presented in Figures 33 and 34. For this right-handed subject, there was an initial left-hand dynamometer score of 51.5 kg, which improved to roughly 60 kg by the end of the study. With the right hand, he obtained an initial score of 57.5 kg. He obtained a final measurement of 64 kg. Visual inspection suggested that there was a gradual improvement for the left hand, whereas the right-hand scores appeared equivocal. The binomial test suggested significant improvement for the left-hand scores ($p<.03$) and no improvement with treatment for the right-hand scores ($p<.61$). Of the 28 treatment data points, 18 were above the curves projected from baseline measures.

Insert Figures 33 and 34 (p. 65)

L1: The results for the left- and right-hand two-point thresholds are presented in Figures 35 and 36, respectively. The initial left-hand threshold was 8 mm. The final threshold was 6 mm. For the right hand the first measure was 10 mm and the last was 5 mm. Both visual inspection of the plotted data and the binomial test for both hands indicated that there was no improvement (left =p<.50; right =p<.99) of two-point sensory thresholds during the treatment sessions. Of the 14 treatment data points, only 5 were in the improved direction from the curves projected from baseline data.

Insert Figures 35 and 36 (p. 67)

The results for the dynamometer scores in this left-handed subject are presented in Figures 37 and 38 for the left and right hand, respectively. Initially, the left-hand grip strength was 17.5 kg, and on the final measure it was 22 kg. The right hand yielded a grip of 29.5 kg, initially, which changed to 37 kg. However, both visual inspection and the binomial test indicated that the increases in these scores were not significantly different (left =p<.94; right =p<.50) from what one would predict from the baseline periods. Of the 14 treatment data points, only 6 were above the curves projected from baseline sessions.

Insert Figures 37 and 38 (p. 67)

L2: The results for left and right two-point thresholds are presented in Figures 39 and 40, respectively. Initially, the left-hand two-point threshold was 9 mm. It was also 9 mm on the final experimental session. The right-hand threshold was, at first, 6 mm; and again, 6 mm, at the last assessment. Visual inspection revealed variable performance on two-point thresholds for both hands. Judgment of improvement was difficult on the basis of the graphs alone. The binomial test suggested that there was no significant improvement for either the left- ($p<.23$) or right-hand ($p<.23$) thresholds. Of the 14 treatment data points, for both hands together, 10 were improved from the curves projected from the baseline sessions.

Insert Figures 39 and 40 (p. 69)

The results for left and right grip strength are presented in Figures 41 and 42, respectively. This left-handed subject first obtained a left dynamometer score of 26 kg, which improved to 35 kg by the end of the study. On the right hand, he initially achieved a score of 31 kg, which increased to 39.5 kg by the last session. Visual inspection of the graphs suggested gradual improvement throughout the study. The binomial test indicated that the left-hand measurement improved significantly ($p<.01$). The right-hand score change approached significance ($p<.06$). Of the 14 treatment data points, for both hands together, 13 were above the curves projected from the baseline sessions data.

Insert Figures 41 and 42 (p. 69)

L3: The results for left and right two-point sensory thresholds are presented in Figures 43 and 44, respectively. Initially, the left-hand threshold was 8 mm, and on the last session it was 6 mm. The initial right-hand score was 6 mm, and the final score on the right was 10 mm. Both visual inspection and the binomial test indicated that no improvement (left $=p<.94$; right $=p<.77$) occurred for L3 on two-point sensory thresholds during this study. Of the 14 treatment data sessions, for both hands, only 5 improved over the levels projected from the baseline sessions.

Insert Figures 43 and 44 (p. 70)

The results for grip strength for this right-handed subject are presented in Figures 45 and 46. The left hand showed an initial score of 31.5 kg. At the end of the study, a score of 30 kg was achieved. The right hand first obtained a score of 31 kg, and, on the last session, a score of 34.5 kg. Both visual inspection and the binomial test suggested that no improvement of grip strength (left $=p<.77$; right $=p<.50$)

occurred during this study in either the right or left hands. Of the 14 treatment data points, for both hands, 7 were above the levels predicted from the baseline data.

Insert Figures 45 and 46 (p. 70)

L4: The results for two-point sensory discrimination are presented in Figures 47 and 48. The left hand began with a score of 10 mm and obtained a score of 8 mm at the end of the study. The right hand first had a score of 5 mm and also obtained a score of 5 mm on the last session. Visual inspection of the plotted data points suggested that there was improvement over time, though this was difficult to ascertain, due to the variability of the scores. The binomial test, however, indicated that significant improvement did not occur for either the left ($p<.23$) or right hand ($p<.50$). Of the 14 treatment data points, 9 were improved from the levels predicted from the baseline sessions.

Insert Figures 47 and 48 (p. 72)

The results for L4's dynamometer scores are presented in Figures 49 and 50. Initially, this right-handed subject obtained a left-hand score of 41 kg. The final left-hand score was 51 kg. The initial right-hand score was 43.5 kg, and the score for the last session was 53 kg. Both visual inspection and the binomial test suggested that there was no significant improvement (left =$p<.50$; right =$p<.23$) during the treatment sessions. Of the 14 treatment data points, 9 were above the curves projected from baseline.

Insert Figures 49 and 50 (p. 72)

L5: The results for left- and right-hand two-point sensory discrimination are presented in Figures 51 and 52, respectively. Initially, the left two-point threshold score was 8 mm, which went to 3 mm by the end of the study. On the right hand, the initial threshold score was 6 mm, and the final score was 6 mm. On visual inspection, variable performance occurred on the left, which made it difficult to judge improvement, if any, for this data. The binomial test for the left-hand scores suggested that no improvement occurred ($p<.77$). The right-hand scores also showed variability, and the binomial test indicated that there was no improvement ($p<.99$). Of the 14 treatment data points, for both hands combined, only 4 were above the projected levels from the baseline measures.

Insert Figures 51 and 52 (p. 74)

The results for L5's grip strength scores are presented in Figures 53 and 54. There, it was observed that this right-handed subject initially obtained scores of 37 kg and

39 kg for his left and right hand, respectively. At the final session of the study, he received scores of 31 kg and 32.5 kg; for his left and right hand, respectively. Both visual inspection and the binomial test (left =p<.94; right =p<.999) indicated that these scores did not improve during this study. Of the 14 treatment data points, only 2 were above the projected levels predicted from the baseline scores.

Insert Figures 53 and 54 (p. 74)

In summary, the findings on sensory and motor testing used to evaluate hypothesis two showed that, of the 9 subjects, only 1 (from the Early treatment group) improved their two-point sensory threshold significantly with both hands. One other patient (also from the Early treatment group) showed improved two-point threshold scores on one hand, but not the other. Thus, 7 of the 9 patients did not show improvment on this task during this study. Of the total number of treatment data points across all subjects (total= 182), 102 (or 56%) were above the projected levels from baseline measures.

The overall results on the grip strength scores showed a similar pattern. Only 1 subject (who was in the Early treatment group) showed significantly improved bilateral dynamometer scores. Three other subjects (2 from the Early treatment group and 1 from the Late treatment group) showed a significant unilateral improvement. Furthermore, of the total 182 treatment data points across all 9 subjects, 100 (or 55%) were above the curves projected from the baseline data points. This suggested that light threshold treatment did not improve two-point sensory thresholds or grip strength.

We now turn to consider the possible effects light threshold treatment had on repeated numeral reading speed and accuracy.

E1:The results for repeated numeral reading are presented in Figures 55 and 56, respectively. Initially, she required 103 s to read the 100 numerals. By the last session, she read these in 59 s. Figure 56 showed that she made only 1 error, on session 10, throughout the entire study. Such a low error score suggested that this task was not difficult for this subject and that there was little room for improvement from the beginning. Thus, it was apparent that no change occurred during this study on the number of errors made while performing the repeated numeral reading task. Visual inspection of the reading speed data indicated that she improved over the course of the study. Of the 14 treatment data points, 13 were below (the improved direction) the level projected from her baseline scores. This was significant ($p<.001$) and suggested that the treatment improved her reading speed above the levels predicted from the baseline scores. The result for the error scores was not significant ($p<.999$).

Insert Figures 55 and 56 (p. 60)

E2: The results for E2 on the repeated numeral reading task are presented in Figures 57 and 58, respectively. Initially, the reading speed was 89 s, and, by the final session, it was at 70 s. Visual inspection showed a gradual decrease in time but not enough to suggest significant improvement. The binomial test also indicated that no significant improvement ($p<.97$) occurred, with only 4 of the 14 treatment data points appearing below (the improved direction) the curve projected from the baseline scores. The error score for this subject was very low throughout the study showing an apparent ceiling effect similar to E1. The binomial test for the error scores was also not significant ($p<.09$).

Insert Figures 57 and 58 (p. 62)

E3: The results for reading speed and accuracy are presented in Figures 59 and 60, respectively. Initially, the subject read the stimuli at 122 s; by the end of the study, he required only 106 s. He made 10 errors during the first assessment but quickly improved this during the baseline sessions. By the end of the study, he was making 1 error per session. Visual inspection and the binomial test showed striking improvement in reading speed during the light threshold treatment sessions ($p<.0001$), with all 14 treatment data points below the projected baseline curve. Inspection of the reading error scores revealed no change ($p<.99$) associated with the treatment sessions. This suggested a ceiling effect for the error score.

Insert Figures 59 and 60 (p. 63)

E4: The results for repeated numeral reading speed and accuracy are presented in Figures 61 and 62, respectively. Initially, this task was completed in 122 s; by the end of the study, it was done in 69 s. Visual inspection and the binomial test suggested that the repeated numeral reading speed improved significantly during this study ($p<.001$). Visual inspection of the error scores again revealed that very few errors were made throughout this study, and that no significant change ($p<.61$) occurred for this patient during the treatment sessions.

Insert Figures 61 and 62 (p. 65)

L1: The results for repeated numeral reading speed and accuracy are presented in Figures 63 and 64. Initially, this patient was discontinued on this task after 10 min (or 600 s), during the first three baseline sessions. At end of the study, he completed this task in 549 s. A similar pattern was obtained for the error score, with 99 errors made on the first session, and 23 errors made on the last session. Visual inspection of the graphed data for both speed and accuracy indicated considerable variation in performance. Neither graph suggested a treatment effect. The binomial tests for speed (p<.94) and errors (p<.77) were also not significant. Of the 14 treatment data points for the speed of reading score; only 2 were improved from levels predicted from baseline. Of the 14 treatment data points for the error score, 3 were improved from the levels predicted from baseline.

Insert Figures 63 and 64 (p. 67)

L2: The results for repeated numeral reading speed and accuracy are presented in Figures 65 and 66, respectively. Initially, the task was completed in 118 s; at the end of the study, it was completed in 86 s. Visual inspection suggested that there may have been a treatment effect, and the binomial test indicated that this was significant (p<.01). All 7 of the treatment data points were above the curve projected from baseline. Inspection of the error scores showed few errors during the study, with no apparent change. However, the binomial test indicated a significant effect for treatment (p<.01), in that all the treatment data points were slightly improved from the curve projected from the baseline data.

Insert Figures 65 and 66 (p. 69)

L3: The results on the repeated numeral reading task are presented for subject L3 in Figures 67 and 68. Initially, he completed the task in 162 s. On the last assessment, he completed it in 125 s. With repect to errors, he initially made 11 errors; but, on the final session, he made only 1 error. For both the time and error scores, there appeared to be a gradual improvement throughout the study. The binomial test indicated a significant treatment effect ($p<.01$) for both the error scores and speed of reading times. For both measures, all of the treatment data points were improved from the levels projected from the baseline sessions.

Insert Figures 67 and 68 (p. 70)

L4: The results on the repeated numeral reading task for L4 are presented in Figures 69 and 70. Initially, this task required 102 s for completion. On the final session, it was done in 79 s. Few errors were made. Visual inspection suggested no change during the study despite the binomial test, which indicated that error scores approached statistical significance ($p<.06$). Visual inspection of the time scores suggested an improvement concurrent with the treatment sessions; the binomial test also suggested that these approached statistical significance ($p<.06$). Of the 7 treatment data points for speed of reading scores, 6 were improved from the levels projected from the baseline measures. This was also the case for the error scores.

Insert Figures 69 and 70 (p. 72)

L5: The results for the repeated numeral reading test for L5 are presented in Figures 71 and 72. Initially, he required 70 s to finish this task; on the last session, he completed it in 59 s. Both visual inspection and the binomial test ($p<.01$) suggested a significant treatment effect for reading speed. All 7 of the treatment data points were improved from the levels projected from baseline. As for the error scores, it was apparent that very few errors were made on this task. However, the binomial test approached significance ($p<.06$) for the error scores.

Insert Figures 71 and 72 (p. 74)

In summary, the repeated numeral reading test scores showed that 6 of the 9 subjects exhibited a significant improvement in speed. Two showed improved error scores. Taken altogether, across all subjects in the study, of the 91 treatment data points for repeated numeral reading speed, 74 (or 81%) were above the levels projected from the baseline measures. Of the 91 treatment data points for errors, 49 (or 54%) were improved from the baseline projected levels. Thus, the results suggested that there was a significant effect (when analyzed with the binomial test for significance) for light threshold treatment on the speed of numeral reading, but not for errors. The results for the error score were probably due to a ceiling effect: Most subjects made so few errors on this task throughout the study that change could not be adequately evaluated.

Mean intercorrelations were calculated across all subjects for those measures repeated on each of the 17 experimental sessions. The number of subjects with a significant correlation (Maximum = 9) between measures was noted. These intercorrelations and frequencies are presented in Table 3.

Insert Table 3

Three significant mean intercorrelations were evident. The left visual field target detection score significantly correlated with the right visual field target detection score ($r=.67$, $p<.01$). The correlation between right visual field target detection and repeated numeral reading time was also significant ($r=-.57$, $p<.05$). This suggested that as the right visual field score improved, the completion time for the repeated numeral reading task decreased. The correlation between the left visual field and repeated numeral reading speed also approached significance.The final

TABLE 3

Intercorrelation Matrix of Repeated Measures

Task:	LVF	RVF	L2P	R2P	LGS	RGS	RNRT	RNRE
LVF	--	+7**	-1	+1	+1,-1	+1,-1	-4	-2
RVF	.67**	--	-2	-1	+3,-2	+1,-1	-6*	-3
L2P	-.05	-.23	--	0	+1	+1	+2	0
R2P	.06	-.11	.13	--	+1,-1	-1	0	+2
LGS	.10	.15	.04	.01	--	+7**	+1,-2	+1,-1
RGS	.05	.09	.05	-.10	.62**	--	+2,-1	-2
RNRT	-.42	-.57*	.25	.17	-.16	-.07	--	+3
RNRE	-.18	-.24	-.02	.07	-.10	-.21	.26	--

Table 3. The lower left half shows the mean correlations across subjects for each task. The upper right shows the number of subjects (out of 9) with a significant correlation. The direction of correlation is also indicated. LVF=Left Visual Field, RVF=Right Visual Field, L2P=Left Two-point Threshold, R2P=Right Two-point Threshold, LGS=Left Grip Strength, RGS=Right Grip Strength, RNRT=Repeated Numeral Reading Time, RNRE=Repeated Numeral Reading Errors. For correlation data ** = ($p<.01$), * = ($p<.05$). Frequency data marked ** and * correspond to significant correlations.

significant correlation occurred between left- and right-hand grip strength scores ($r=.62$, $p<.01$).

The frequency of subjects with significant correlations corresponds to the mean intercorrelation data in that 7 subjects had significant positive correlations between the left and right visual field and between left and right grip strength. There were 6 subjects with significant negative correlations between the right field and repeated numeral reading speed and 4 with a negative correlation between the left field and numeral reading speed.

We now turn to evaluate the effect of light threshold training on the standardized measures of reading. These measures were, as listed above in the methodology section, the Chapman-Cook Speed of Reading Test, the Wide Range Achievement Test (Reading Subtest, Level II), and the Gates-MacGinitie Reading Test (Comprehension Subtest, Survey E).

Assessments of both speed and accuracy were collected for each of these tests on O1, O2, and O3. The raw scores are presented in Appendix D. The mean scores for both treatment groups are presented in Figures 73 through 78.

Insert Figures 73 - 78

To evaluate treatment effect, a percent change score from O1 to O2 was calculated. These percent change scores were then rank-ordered so that a Mann Whitney U test of

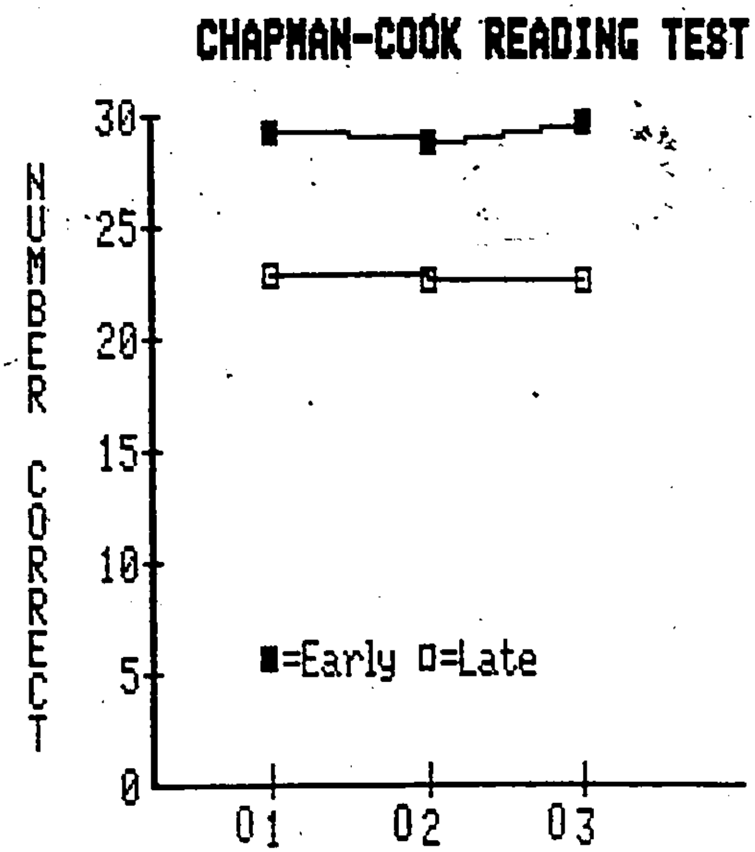

Figure 73. Graph shows mean correct score for both groups on the three test days.

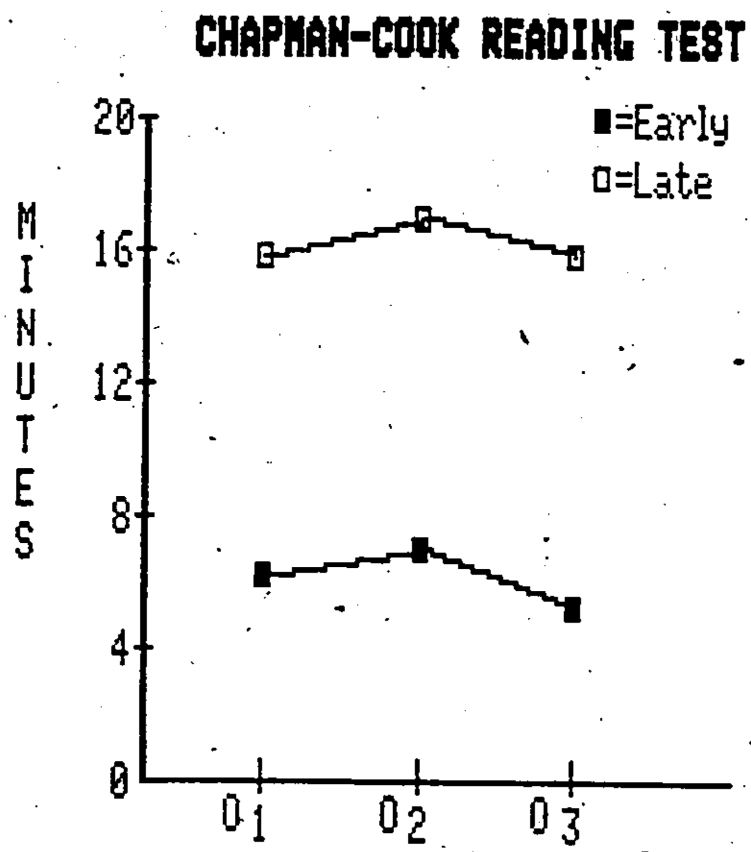

Figure 74. Graph shows the mean time required for each group on each of the three test days.

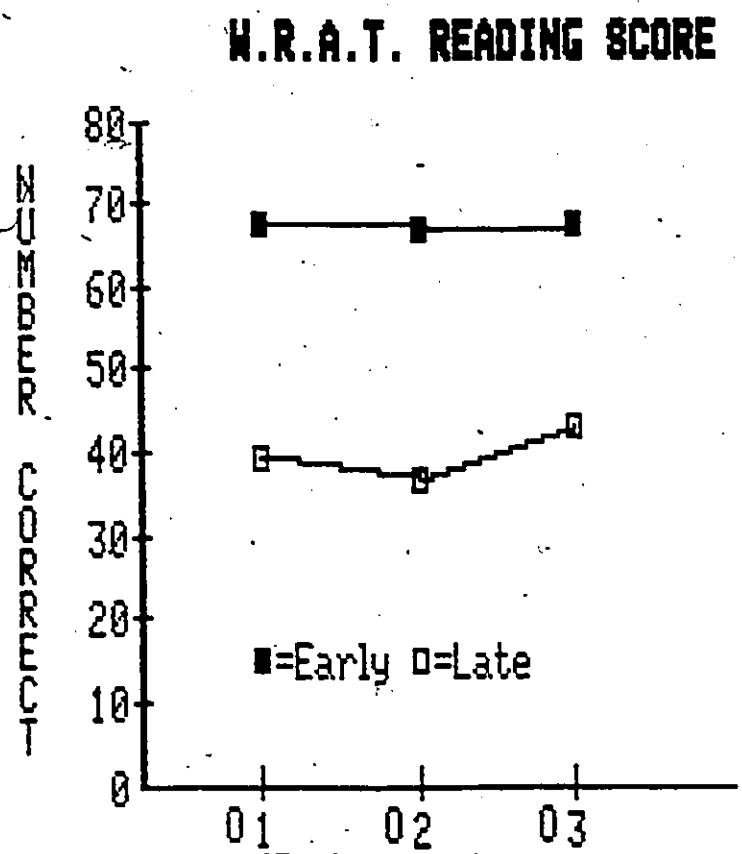

Figure 75. Graph shows mean scores for the two groups on each of the three test days.

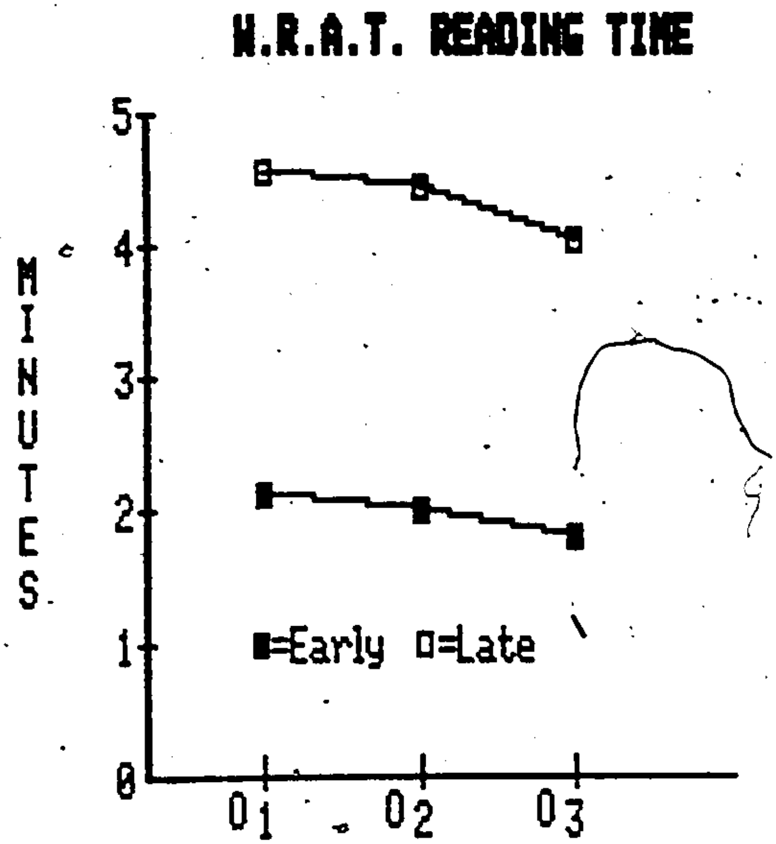

Figure 76. Mean times for both groups to complete the W.R.A.T. reading test on each of the three test days.

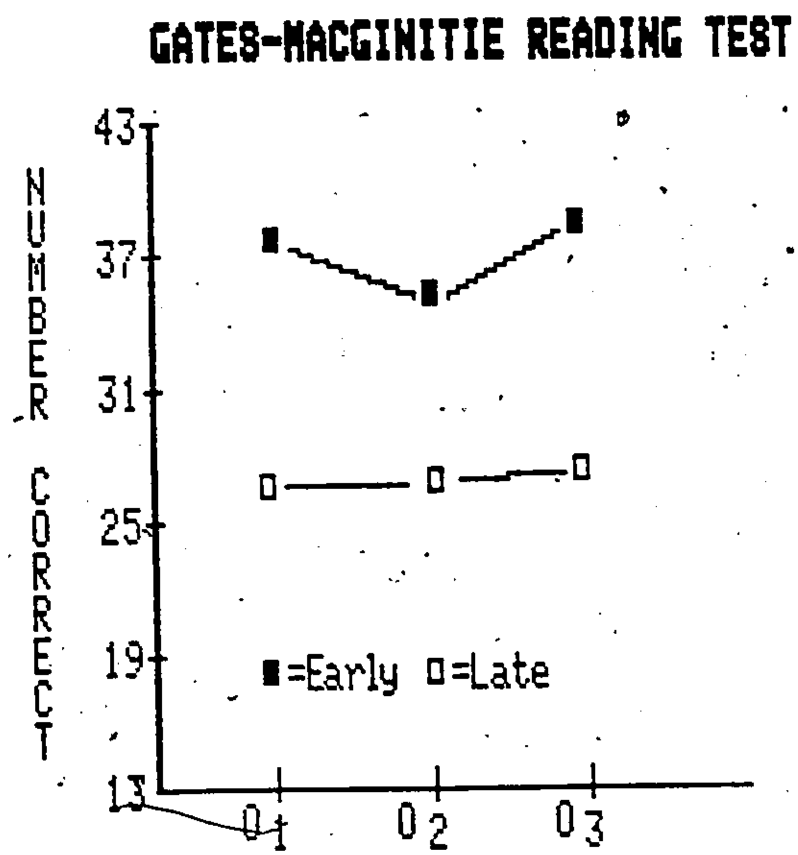

Figure 77. Graph shows mean number correct for both groups on each of the observation days.

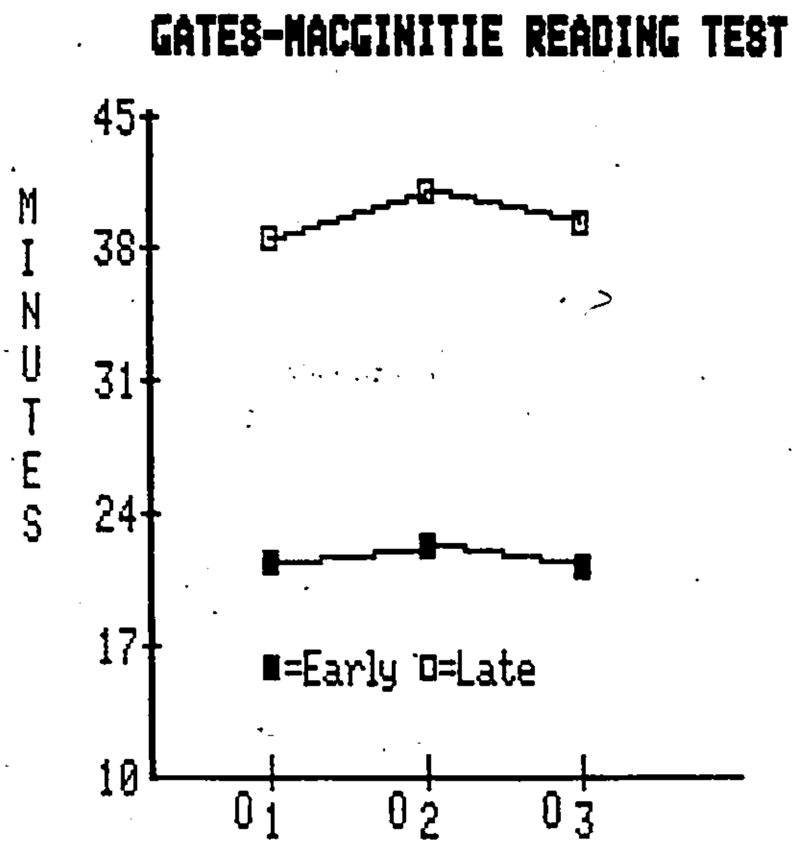

Figure 78. Graph shows mean times for both groups on each of the three test days.

significance could be calculated. This allowed a comparison of the groups at a time when the Early treatment group had received six sessions of light threshold training and the Late treatment group had received none. The percent change scores for the three standardized reading tests are presented in Table 4.

Insert Table 4

Inspection of the scores for the Chapman-Cook Speed of Reading Test revealed that there was no treatment effect for either the percent change in test scores for accuracy ($U=10$, $p<.50$) or for the percent change in the speed with which the task was completed ($U=9$, $p<.452$).

The results for the Wide Range Achievement Test (WRAT) also showed no treatment effect for either the percent change in reading score ($U=8.5$, $p<.4085$) or the percent change in the time taken to finish the test ($U=9$, $p<.452$).

Similarly, there were no significant differences between the Early group which had received the training, compared to the Late group which had not, on the Gates-MacGinitie Reading Test percent change scores ($U'=11.5$, $p<.592$), or on the time scores ($U'=12$, $p<.635$).

In summary, there were no significant differences between the two groups. This suggested that the light threshold training had no significant effect on either reading

TABLE 4

Results of Standardized Reading Tests

Subject	Chapman-Cook Score	Chapman-Cook Time	W.R.A.T. Score	W.R.A.T. Time	Gates-MacGinitie Score	Gates-MacGinitie Time
E1	3.5%	-12.8%	4.1%	5.0%	2.6%	-19.4%
E2	-3.3%	2.4%	-2.7%	-56.1%	10.3%	-24.2%
E3	-6.7%	-2.4%	0%	15.9%	-22.6%	-4.6%
E4	0%	-32.6%	-2.9%	14.6%	-20.0%	20.9%
L1	0%	0%	0%	0%	0%	0%
L2	3.5%	-81.4%	-11.8%	29.0%	2.6%	-53.3%
L3	-7.7%	-13.3%	-45.5%	-23.0%	5.6%	9.4%
L4	-3.3%	-1.8%	9.1%	2.2%	-3.0%	3.8%
L5	0%	-11.0%	-1.3%	10.3%	0%	3.3%

Table 4 shows the percent change scores from O1 to O2 for each subject on standardized reading tests. E1-4= Early treatment subjects, L1-5 = Late treatment subjects. Positive scores indicate improvement, negative a decline.

accuracy or speed as measured by these standardized reading tests.

Next, the data relevant to evaluate treatment effects on the Goldmann visual fields are presented. The raw data area scores (in square millimeters) for O1, O2, and O3 are presented in Appendix D. The mean scores for the Early and Late treatment groups are presented for visual inspection (see Figure 79).

Insert Figure 79

Percent change scores from O1 to O2 were calculated. These scores are presented in Table 5.

Insert Table 5

These percent change scores were then rank-ordered and a Mann Whitney U test of significance was performed for each visual field (across both eyes, except for subject L1 who received Goldmann Perimetry in only his right eye). This allowed a comparison of percent change scores between the Early treatment group and the Late treatment group at a time when the Early group had received six training sessions and the Late group had received none. The results showed no significant difference between the two groups for either the

TABLE 5

Results of Goldmann Perimetry

Subject	Left Visual Field		Right Visual Field	
E1	7.8%	*	1.4%	
E2	11.3%		58.3%	*
E3	-13.9%		-100.0%	*
E4	201.2%	*	12.6%	
L1	71.0%	*	13.6%	
L2	-5.0%	*	-4.3%	
L3	251.5%	*	4.8%	
L4	-0.6%		31.2%	*
L5	2.7%		2.6%	*

Table 5. Percent change area scores from 01 to 02 on Goldmann visual fields for both groups. The asterisk denotes the field more impaired by scotoma or hemianopia and, hence, represents the field subjected to light threshold training.

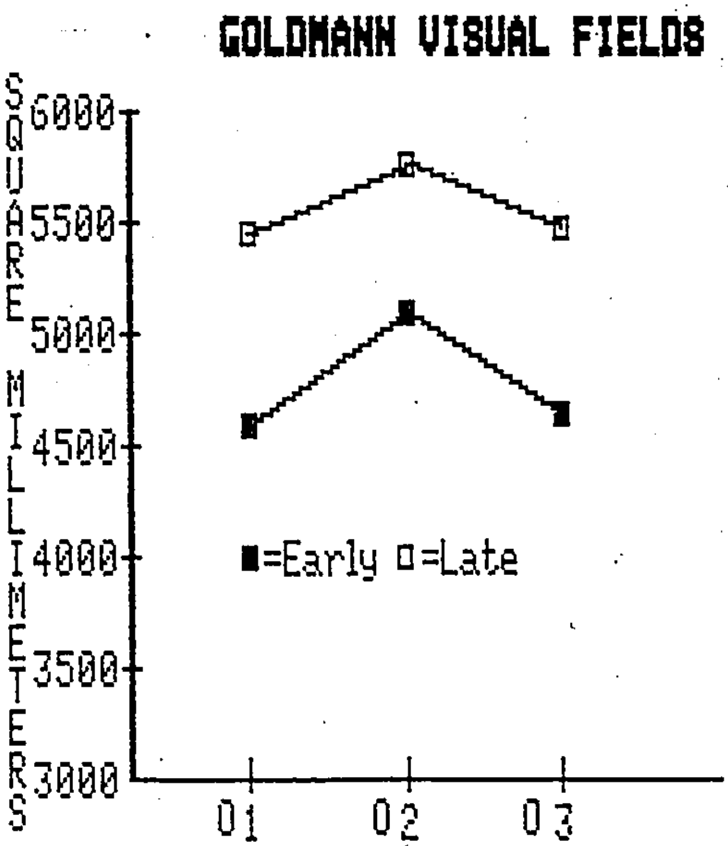

Figure 79. Graph shows Goldmann field mean area scores for both groups on each of the three observation days.

left visual field (U=10, p<.50) or the right visual field (U'=11, p<.548). This suggested that there were no treatment effects on Goldmann Perimetry for the six light threshold training sessions. Close inspection of the data revealed that the pronounced improvement in the percent change scores (see Table 5) corresponded to the visual field with the greater visual defect. Thus, 6 (3 Early and 3 Late subjects) of the 9 patients demonstrated more improvement in their visual field with the greater field defect. This suggested more variability (in the direction of improvement) in performance on the Goldmann Perimeter for visual fields with scotoma or hemianopsia. This may also reflect a possible ceiling effect for visual fields which are relatively defect-free.

Finally, the results pertinent to evaluate everyday vision are presented. The raw data for the five measures of "everyday" visual abilities (specifically: "H" Cancellation, Box Search, Line Bisection, Visual Search, and Visual Scanning) are presented in Appendix D. The mean scores for the Early and Late treatment groups are presented in Figures 80 through 93.

Insert Figures 80 - 93

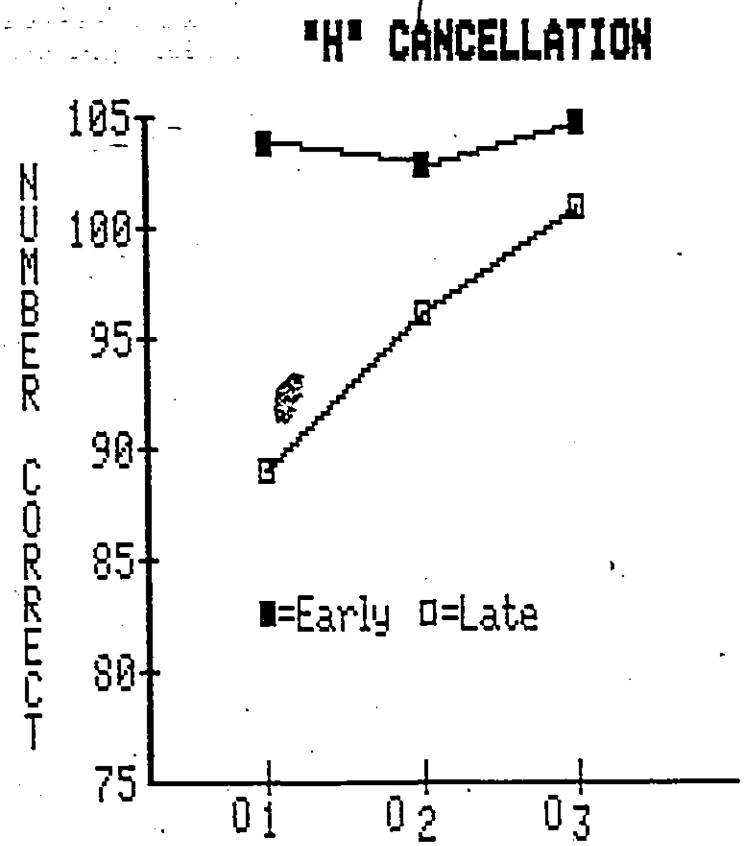

Figure 80. Graph shows means number correct for both groups on each of the three test days.

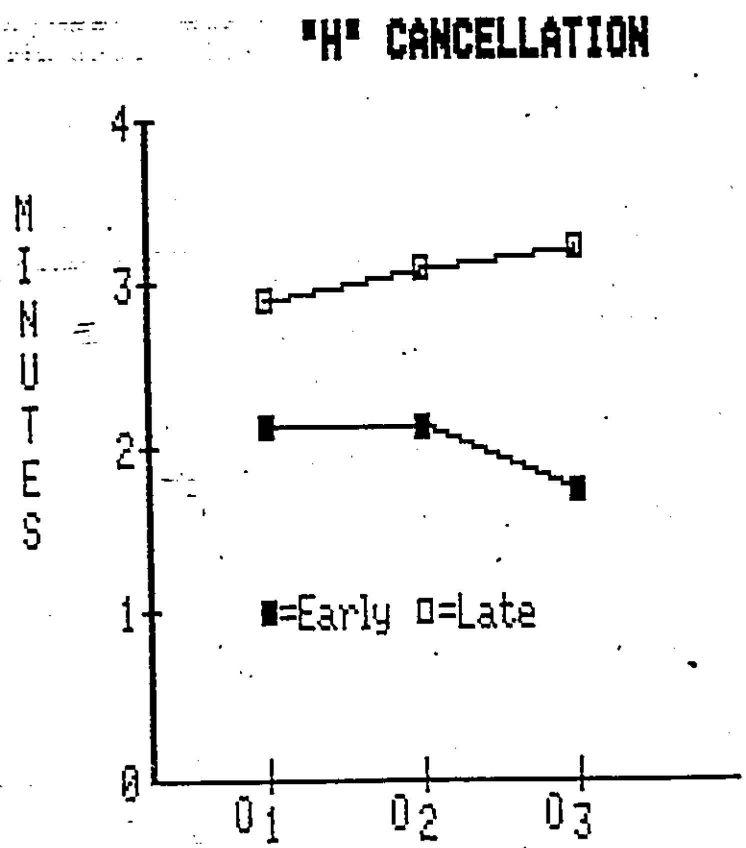

Figure 81. Graph shows mean times for both groups on each of the three test days.

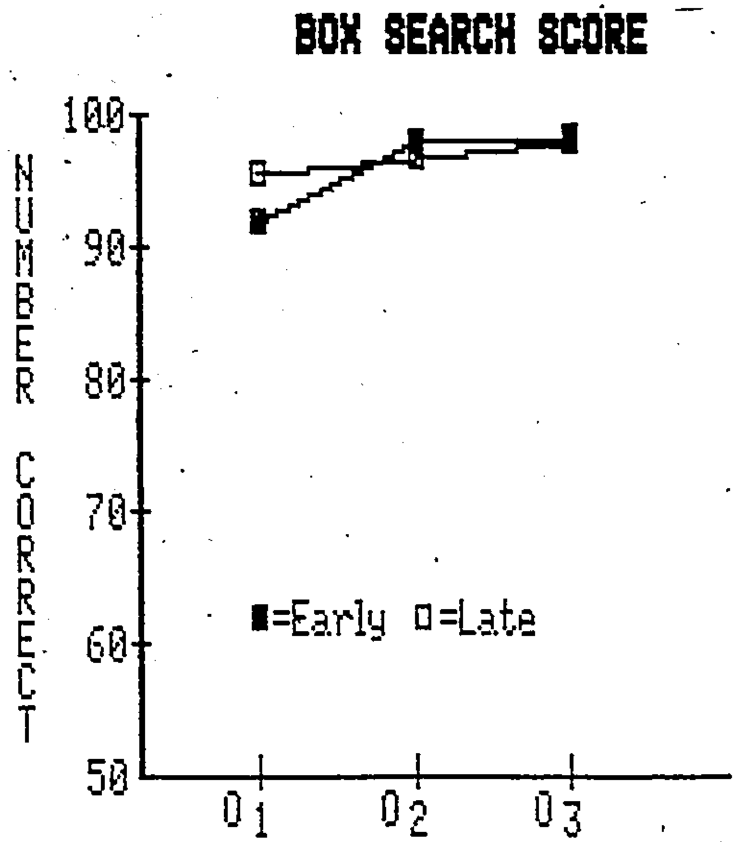

Figure 82. Graph shows mean number correct for both groups on each test day.

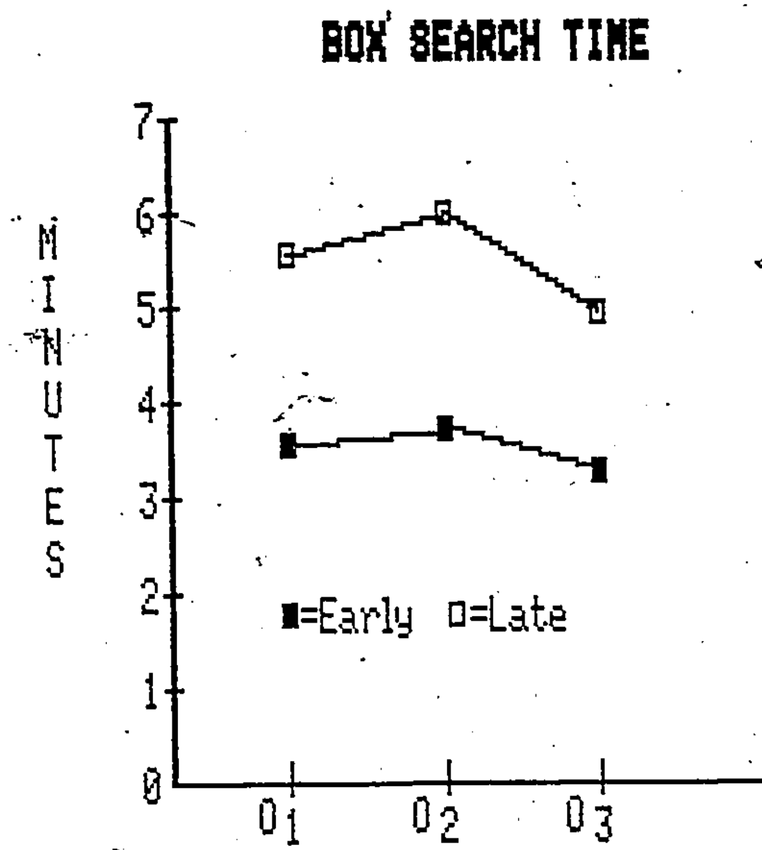

Figure 83. Graph shows mean times for both groups on each of the three test days.

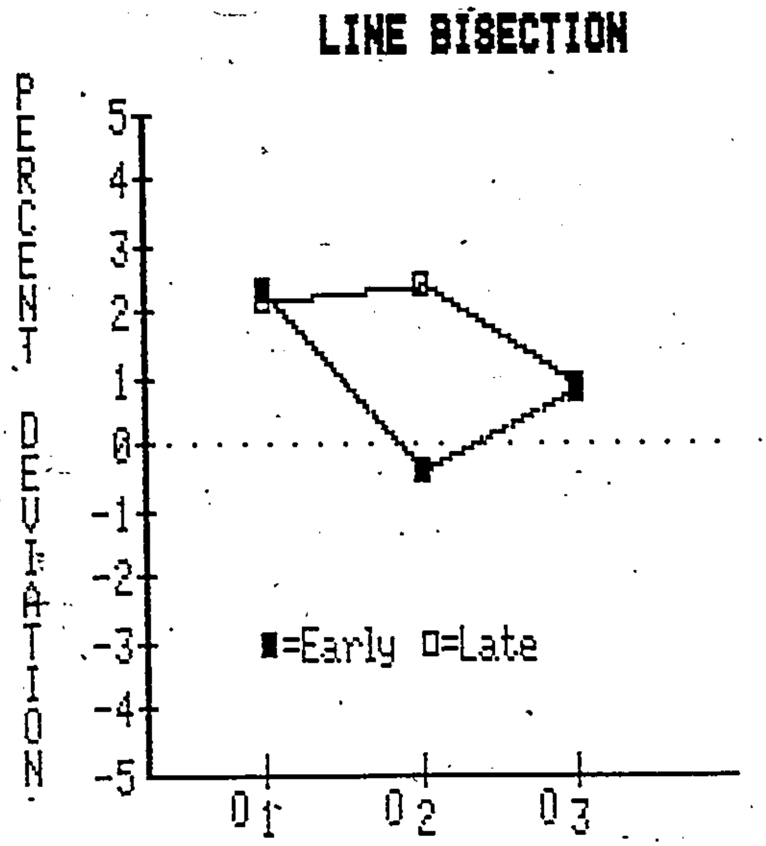

Figure 84. Graph shows mean percent deviation scores. Positive scores indicate right deviation, negative indicate left.

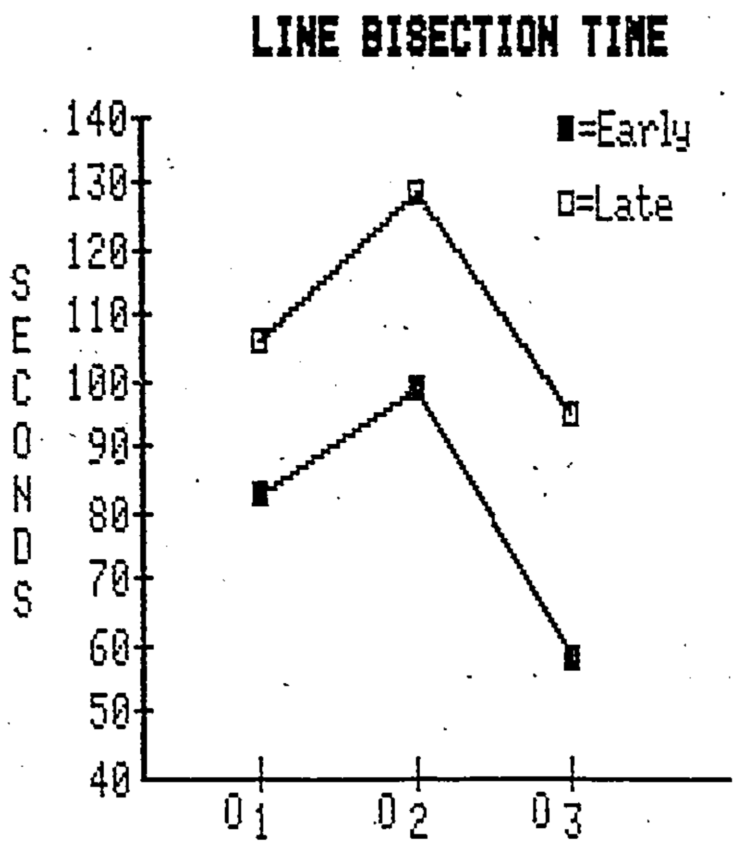

Figure 85. Graph shows mean times for both groups on the three test days.

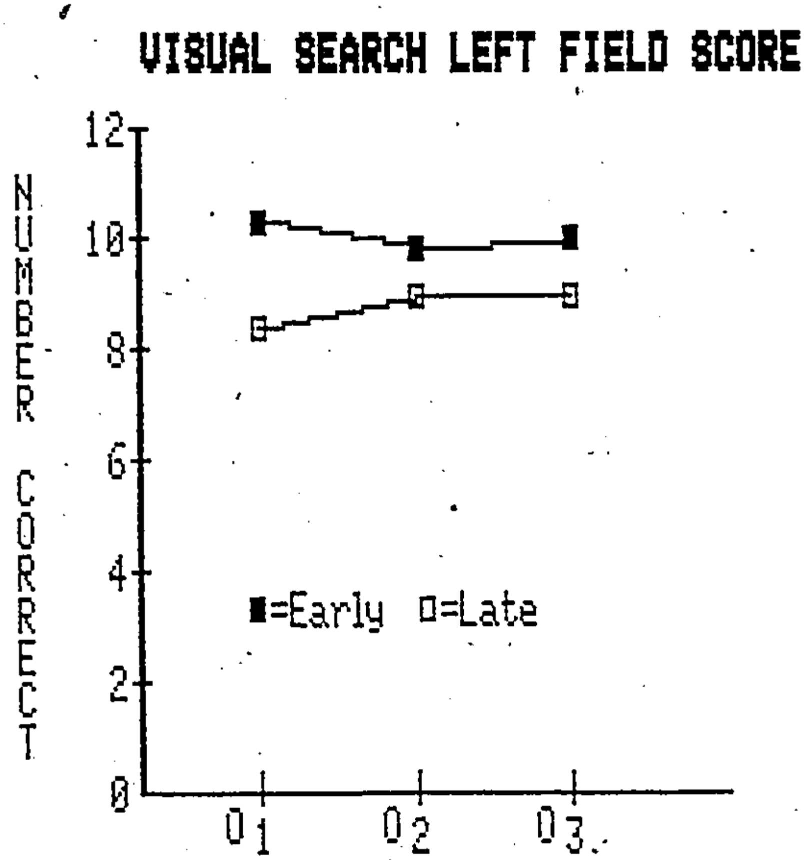

Figure 86. Graph shows mean score for both groups on each test day.

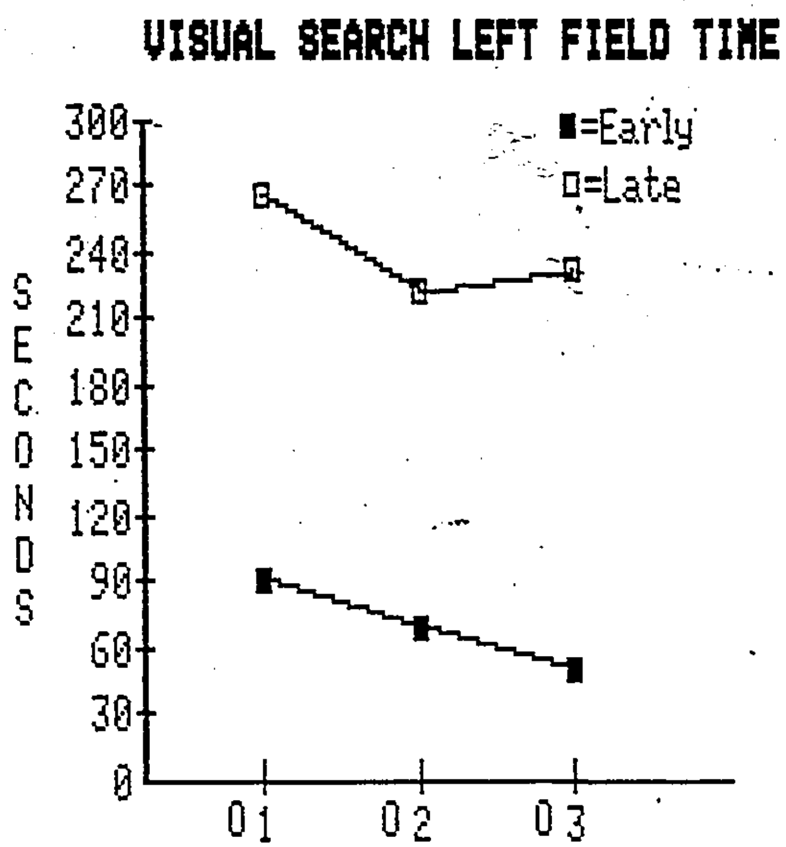

Figure 87. Graph shows mean times for both groups on the three test days.

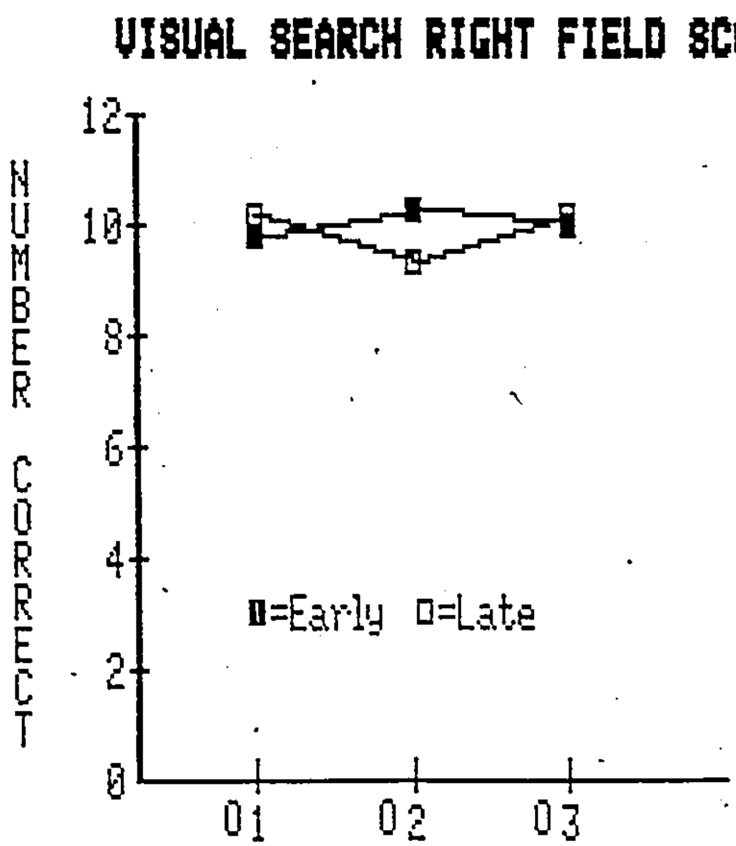

Figure 88. Graph shows mean right field scores for both groups on each test day.

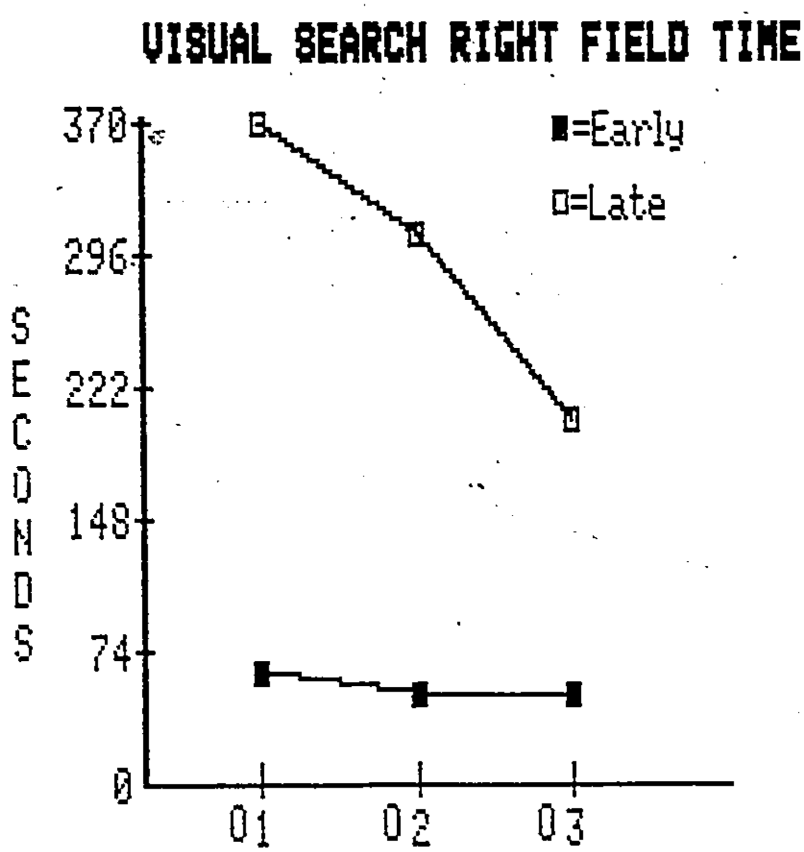

Figure 89. Graph shows mean time for both groups on each test day.

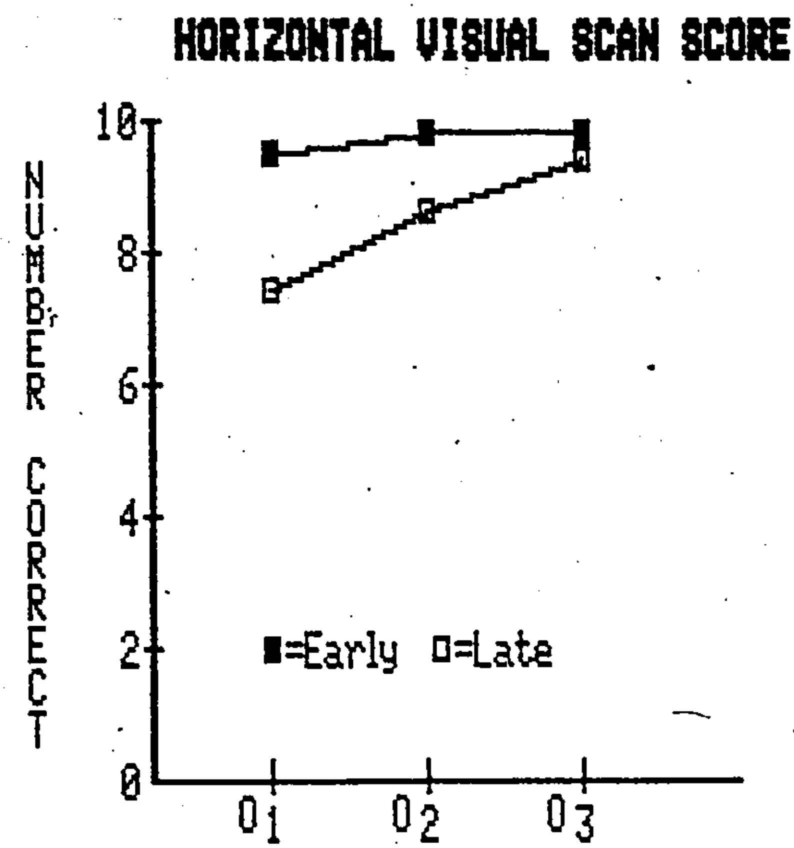

Figure 90. Graph shows mean scores for both groups on each of the test days.

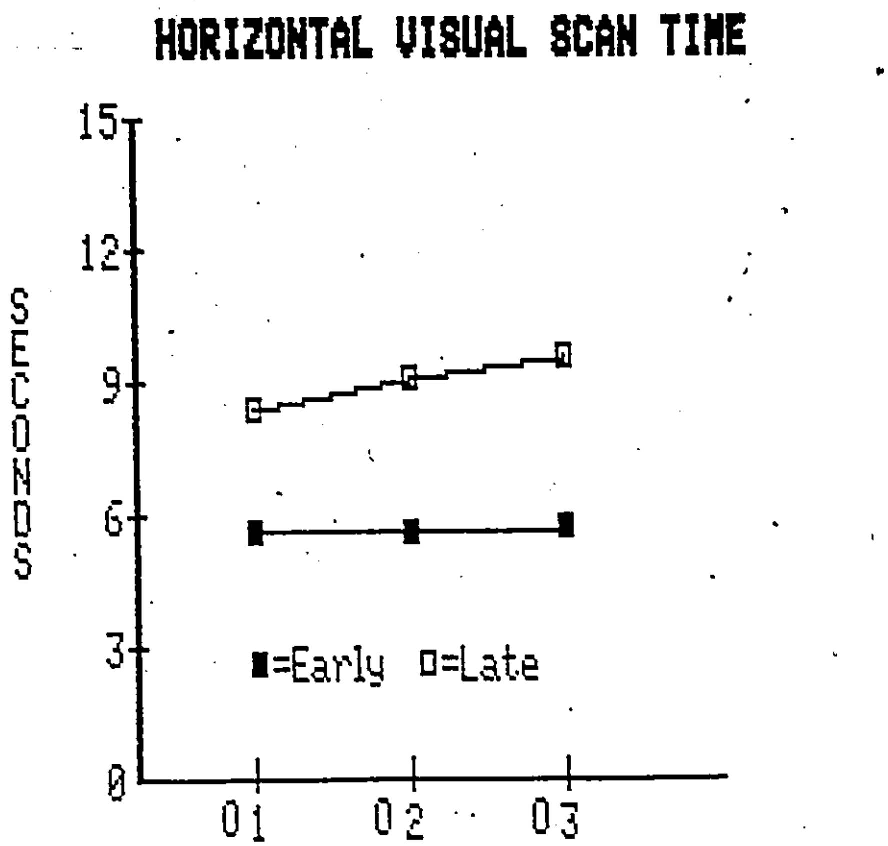

Figure 91. Graph shows mean times for both groups on each of the test days.

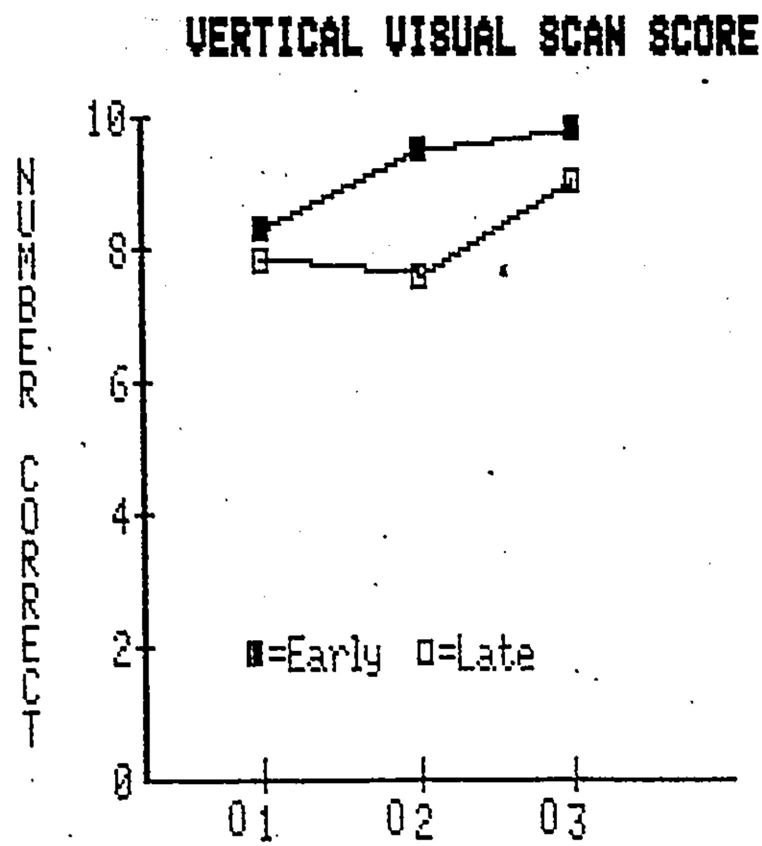

Figure 92. Graph shows mean score for both groups on each of the test days.

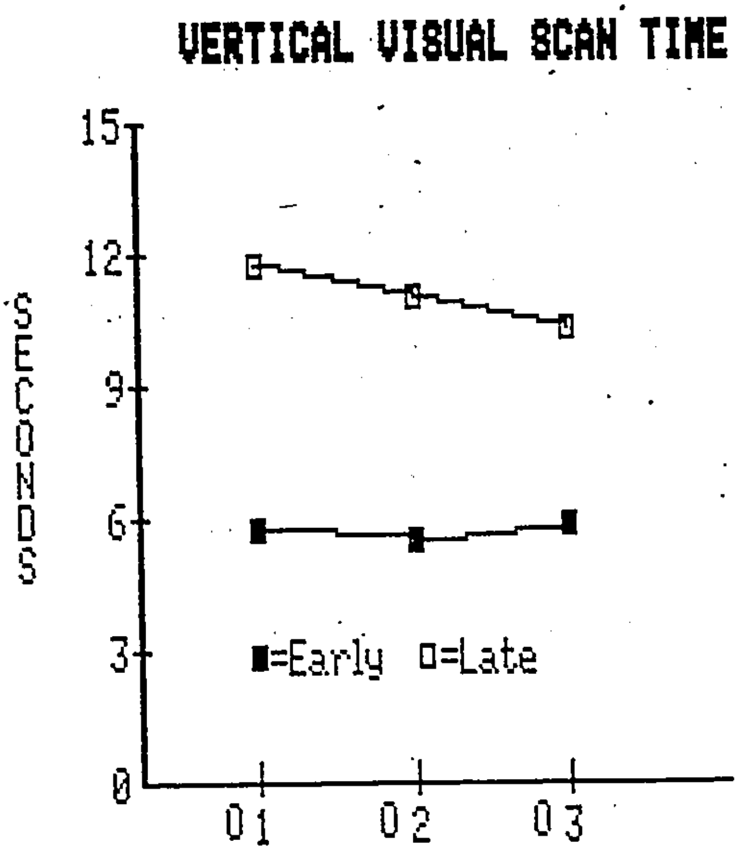

Figure 93. Graph shows mean times for both groups on each of the test days.

The results of the percent change scores, allowing an evaluation of the light threshold training, are presented in Table 6.

Insert Table 6

Using the Mann Whitney U test to evaluate the statistical significance between the groups, no apparent treatment effect was found for "H" Cancellation scores ($U'=16.5$, $p<.925$) or time taken to complete the task ($U=9$, $p<.452$); for Box Search scores ($U=8.5$, $p<.409$) or times ($U'=11$. $p<.548$); for Line Bisection deviation scores ($U'=15$, $p<.86$) or times ($U=10$, $p<.50$); for Visual Search left field scores ($U'=15.5$, $p<.825$) or left field times ($U=7$, $p<.27$); for Visual Search right field scores ($U=5$, $p<.143$) or right field times ($U'=12$, $p<.635$); for horizontal Visual Scanning scores ($U'=18$, $p<.968$) or times ($U=6$, $p<.206$); and finally for vertical Visual Scanning scores ($U=5$, $p<.143$) or times ($U'=11$, $p<.548$). Thus, there were no statistical differences in percent change scores from 01 to 02 between the Early and Late treatment groups.

Summarizing the overall results for this study (see Table 7) evaluation of auto perimetry target detection scores suggested a treatment effect for most subjects.

TABLE 6

RESULTS FOR MEASURES OF "EVERYDAY" VISUAL ABILITIES

SUBJECT	H Cancellation		Box Search		Line Bisection		Visual Search				Visual Scanning			
							Left Field		Right Field		Horizontal		Vertical	
	Score	Time	Score	Time	Score	Time	Score	Time	Score	Time	Score	Time	Score	Time
E1	1.9%	-7.5%	30.1%	-12.8%	-1 %	2.4%	20%	38%	-20%	- 5%	11%	- 1%	- 10%	- 10%
E2	-4.8%	-4.6%	-1.0%	-1.2%	-0.7%	-6.5%	-33%	50%	27%	-26%	0%	- 2%	13%	13%
E3	0 %	5.4%	0 %	1.7%	8 %	0 %	-21%	15%	50%	-31%	0%	-19%	67%	- 4%
E4	0 %	-1.7%	3.1%	-7.1%	-2 %	-33.3%	25%	2%	-17%	64%	0%	13%	11%	9%
L1	81.6%	-13.4%	10.5%	-21.8%	7.5%	-18.7%	25%	17%	-22%	13%	200%	-27%	-100%	-100%
L2	2.1%	-8.2%	-7.3%	4.3%	5 %	-59.1%	-11%	37%	9%	55%	11%	- 6%	0%	21%
L3	1 %	-4.3%	.0 %	0.7%	-0.7%	- 8.3%	38%	-1%	-25%	20%	11%	-22%	- 10%	- 3%
L4	1.9%	1.1%	2 %	7.8%	0 %	3.3%	-17%	5%	25%	43%	11%	21%	- 10%	52%
L5	0%	13 %	1 %	-9.2%	0.5%	11.8%	22%	28%	-18%	-66%	11%	- 2%	25%	- 4%

Table 6. Percent change scores from O1 to O2 for the measures selected to assess "everyday" visual abilities. A positive score indicates improvement. A negative score indicates a decline.

There was also evidence that indicated no treatment effect for sensory and motor tasks believed to be unrelated to treatment and visual skills.

Repeated numeral reading speeds improved for most subjects when given light threshold training. However, there was no effect for the error score, a finding which was likely due to a ceiling effect from so few errors occurring.

Insert Table 7

Mean intercorrelations calculated across subjects on the tasks repeated on the 17 experimental sessions showed unsurprisingly high correlations between left and right visual field scores, and between left- and right-hand grip strength scores. Perhaps somewhat less expected was the significant negative correlation between right field (and almost significant negative correlation between the left field) target detection scores and the speed of numeral reading.

There were no significant differences between the Early and Late treatment groups (from 01 to 02) on the standardized measures of reading. This suggested no treatment effect.

Finally, there were no significant differences (see Table 7) between the Early and Late treatment groups (from 01 to 02) on Goldmann Perimetry or on the other measures selected to assess "everyday" visual abilities. This suggested that

TABLE 7

Summary of Results

Hypothesis	Measure		Number of Patients Showing Improvement (Max.= 9)	Treatment Data Above Baseline Projection	Significant
1	Light Target Detection		6[1]	134/182 (74%)	YES[*]
2	Two-Point Discrimination		2[*]	102/182 (56%)	NO[*]
	Grip Strength		4[4]	100/182 (55%)	NO[*]
3	Repeated Numeral Reading	Speed	6	74/91 (81%)	YES[*]
		Errors	2	49/91 (54%)	NO[*]

GROUP DATA			Mean Percent Change Early	Late	Statistic	Significant
	WRAT	Time	- 5.2%	3.7%	U = 9 (p<.45)	NO[*]
		Score	- 0.3%	- 9.9%	U = 8.5 (p<.41)	NO[*]
	Chapman-Cook Reading	Time	-11.4%	-21.5%	U = 9 (p<.45)	NO[*]
		Score	- 1.6%	- 1.5%	U =10 (p<.50)	NO[*]
	Gates-MacGinitie Reading	Time	- 6.8%	- 7.4%	U'=12 (p<.64)	NO[*]
		Score	- 7.4%	1.0%	U'=11.5 (p<.60)	NO[*]
4	Goldmann Visual Fields	LVF	51.6%	63.9%	U =10 (p<.50)	NO[*]
		RVF	- 6.9%	9.6%	U'=11 (p<.55)	NO[*]
5	"H" Cancel-lation	Time	- 2.1%	- 2.4%	U = 9 (p<.45)	NO[*]
		Score	- 0.7%	17.3%	U'=16.5 (p<.92)	NO[*]
	Box Search	Time	- 4.9%	- 3.6%	U'=11 (p<.55)	NO[*]
		Score	8.1%	1.2%	U = 8.5 (p<.41)	NO[*]
	Line Bisec-tion	Time	- 9.4%	-14.2%	U =10 (p<.50)	NO[*]
		Score	1.1%	2.5%	U'=15 (p<.86)	NO[*]

(Table 7 Continued on next page)

TABLE 7 (Continued)

Visual Search	LVF	Time	26.3%	17.2%	U = 7	(p<.28)	NO[5]
		Score	- 2.3%	11.4%	U'=14.5	(p<.83)	NO[5]
	RVF	Time	0.5%	13.0%	U'=12	(p<.64)	NO[5]
		Score	10.0%	- 6.2%	U = 5	(p<.14)	NO[5]
Visual Scan	Horizontal	Time	- 2.3%	- 7.2%	U = 6	(p<.21)	NO[5]
		Score	2.8%	48.8%	U'=18	(p<.97)	NO[5]
	Vertical	Time	2.0%	- 6.8%	U'=11	(p<.55)	NO[5]
		Score	20.3%	-19.0%	U = 5	(p<.14)	NO[5]

Table 7. Summary of results are shown above. [1]All 6 subjects improved in both visual fields. [2]Significance determined by visual inspection for these data. [3]One patient improved on both hands and the other on one hand. [4]One patient improved on both hands and 3 improved on one hand. [5]Significance determined by Mann-Whitney U Test.

light threshold training did not improve performance on these tasks.

A difference in performance level on the standardized reading tests and visual tasks was noted favoring the Early group. This will be discussed in the next chapter.

Given the extreme variability of the subject L1 and the fact that he received testing and training in only one eye, the results for this study were analyzed a second time excluding his data. Basically, there were no differences found between the initial and second evaluation. His visual field and repeated numeral reading data were similar to the trend present in the initial analysis as were his correlational data (compare to Table 3: LVF & RVF r=.69**; LGS & RGS r=.83**; LVF & RNRT r=-.41; RVF & RNRT r=-.35). Hence, the data on all 9 subjects were included in the results discussed in Chapter 4.

CHAPTER FOUR

DISCUSSION

The data suggested that light threshold training: 1) improved static light target detection (Auto Perimeter) and 2) tended to improve most subjects' repeated numeral reading speed. Mean intercorrelations for the variables measured on each of the 17 experimental days indicated a significant relationship between both visual fields for static light target detection, between both hands for grip strength scores, and between improved right visual field static light target detection and faster repeated numeral reading speeds.

There was no evidence which suggested that light threshold training affected: 1) measures of sensory or motor functions, 2) standardized measures of reading, 3) kinetic light target detection (Goldmann Perimeter), and 4) several measures thought to assess elements of "everyday" visual abilities.

Methodological Considerations

Several methodological issues require discussion. First, the experimental design is somewhat unique in that it employed elements of single-case and group designs. The reasoning behind this choice was presented in Chapter 3 and is not repeated here. However, it should be recalled that the split-middle technique was designed as a descriptive aid rather than as an inferential procedure. The use of the binomial test for significance is not always valid, especially when applied to data that presented a trend during the baseline phase (Barlow & Hersen, 1984). This limitation pertained especially to data obtained during the brief baseline phase of the Early treatment group for this study. There were not enough data points to reveal the true slope of the performance curve. This did not present a problem for the Late treatment group due to the more lengthy baseline phase which allowed a stabilized performance data base from which to project the predicted baseline curve. Nevertheless, the binomial test for significance allowed a summary of the data other than simple visual inspection and has been useful in evaluating other rehabilitative efforts with brain-injured patients (Gianutsos, 1981; Gianutsos & Gianutsos, in press). The use of this design also allowed every subject to receive training at some point in the study. This resolved the ethical problem of control groups.

The second methodological issue for discussion is the low number of subjects in this study. Despite an aggressive attempt to locate and involve as many subjects as possible, there were too few to allow a traditional statistical analysis of the data. Use of the single-case design aided in overcoming this difficulty as did the use of nonparametric statistics. In fact, employing these techniques satisfied some of the recent criticism of traditional designs using "attribute" or "organismic" variables presented in this and most neuropsychological research (Tupper & Rosenblood, 1984). Nevertheless, the limitation of an overall small sample size restricted the generalizations possible from this study.

A third issue is the way in which subjects were assigned to the two treatment groups. Random assignment resulted in unequal initial performance levels between the two groups on several measures. For example, the mean Full Scale I.Q. for the Early group was 114.5, whereas the mean for the Late treatment group was 104. Initial differences were also apparent in attribute variables such as site and size of brain injury, time since injury, and income levels. However, years of educational experience and age were two variables that were similar between the groups. The initial differences between the groups were reflected in the performance level on all the standardized reading test results, with the Early group consistently doing better. This meant that these results required a means of analysis other than performance level. Percent change scores were selected as a means of doing this. There were no differences between the groups when results were analyzed in this fashion. A similar approach was used for analysis of the data on the Goldmann fields and measures of "everyday" vision. Again, no differences were found between the two groups.

The fourth issue is the role practice effects may have had in the two significant effects found for light threshold training in this study. Since it has been reported that practice effects were more likely with three or more administrations of neuropsychological tests to neurological patients (Dodrill & Troupin, 1975), it is possible that the improved target detection and numeral reading speeds were due to practice. Visual inspection of the shift from the baseline phase through the treatment phase for the static light target detection data showed that most subjects improved performance on the light target detection task only after light threshold training began. This improvement then leveled off after several sessions of training and remained improved for the rest of the study. This observation argues against practice effects causing the increase because the increase was seen after training began, despite differences in the length of the baselines.

However, it might be noted that subjects tended to improve light target detection either in both visual fields or not at all. This seems unusual because training was administered only to the visual field with the defect, not both. Several explanations are possible. Training may improve target detection in both visual fields due to a central nervous system process that increases the sensitivity of both fields. There is evidence that this can occur in reverse to the findings in this study. Both Torjussen (1976) and Singer et al. (1977) reported that stimulation of the normal visual field in patients with hemianopsia facilitated visual detection in the impaired field. The results from the current study, however, suggested that training in the impaired field improved light target detection not only in the impaired field but in the normal field as well.

An anatomical explanation for this is possibly found at the retinal level. Careful study of the retina has disclosed many lateral connections and in a sense acts as a nervous centre by itself in that stimulation of one retinal area can inhibit or enhance excitation in other adjacent retinal regions (Davson, 1972; Geldard, 1953). The number of retinal receptors is roughly 150 million, whereas the number of optic nerve fibers is about one million (Davson, 1972). This indicates that many receptors converge on the ganglion cells so that a single optic nerve fiber connects with many bipolar cells which themselves have connections with many rods and cones. The result is that the area of retina over which a light-stimulus may evoke a response in an optic nerve fiber may be quite large. These areas are referred to as the optic nerve fiber's receptive field (Davson, 1972). Thus the improved light target detection found in the results reported in this dissertation may reflect a sensitization of receptive fields at the retinal level. This could explain why improvement was found in both visual fields. However, given the small relative area of these retinal receptive fields this explanation is tenuous and least plausible in explaining the results.

A second possibility is that the treatment resulted in an adaptation or conditioning process that was not possible during the baseline phase. This might be likened to the adaptation that occurred with subjects involved in retinal image displacement or inversion studies (prism glasses). Stratton (1897) was the first to report adaptation of the visual system using inverted retinal images. Others reached similar conclusions (Gibson, 1933; Kohler, 1962). However, more recent work has discounted the theory that it was the visual system that adapted or was conditioned in such studies. Rather, it was position sense or proprioception (Harris, 1966; Rock & Harris, 1967) that adapted. Because the study reported in this dissertation did not require use of position sense to respond to the light targets, it seems unlikely that this provides a reasonable explanation for the results.

A final explanation is that the training helped develop an overall strategy for light target detection that was effective for both fields. However, only one subject (E2) reported during the final debriefing session a strategy for target detection. He indicated that, after the first few sessions, he attempted to quickly move his eyes to detect targets in his periphery. It should be recalled that this subject was one who did not improve with treatment and thus it seems unlikely that a conscious strategy was responsible for the results.

The improved repeated numeral reading speeds showed a more gradual trend for improvement throughout the study. This enhances the likelihood that a practice effect influenced the results. However, most subjects tended to improve beyond the level predicted from baseline performance. Hence, this result may reflect a combination of practice and treatment effects. The fact that improved numeral reading speeds correlated with improved right visual field static target detection scores suggested a further relationship between these measures. This is a finding consistent with other research (Bryden, 1965; Kimura, 1961; Milner, 1971) that indicated a relationship between right visual field functioning and reading abilities. This finding is one of the more interesting results of this study because it suggests a relationship between basic visual field functions such as target detection and a more cognitively complex task such as reading speed. Furthermore, the magnitude of the correlation is such that it compares well with two measures of visual field functioning and two measures of motor functioning. This was an unexpected finding and one which warrants further research.

A fifth issue is the question of improved target detection and numeral reading speeds due to an overall improvement in subject's neurological status. In response to this, it might be recalled that there was no evidence of improvement on several other measures, including grip strength. Grip strength was one measure found to improve as neurological status improved in a group of seizure patients (Seidenberg, O'Leary, Giordani, Berent, & Boll, 1981). Furthermore, the patients in the current study were judged (by their attending physicians) neurologically stable at the beginning and end of this study. Thus, it seems unlikely that the results reflected improved or deteriorated neurological functioning.

The next methodological issue is the role that ceiling effects may have had in the results. For example, the error score for the repeated numeral reading task was low. Almost all subjects performed without errors after the first few trials. This was clearly an easy task and the results were obviously due to a ceiling effect. Another, perhaps less obvious, ceiling effect was demonstrated by the two subjects (E1 and E2) who did not improve on the static light target detection task. From the beginning of the study, they consistently performed very well in detecting most light targets, so that further improvement with training was unlikely. In the second subject's case (E2), this may have been the result of his strategy for detecting the targets reported above. This result suggested that the patients most likely to show improvement with light threshold training were those with initial performance in the moderately to severely impaired range. This is not really stating anything more profound than the well known phenomenon of regression to the mean: extreme scores will tend toward average scores when reassessed. This process was likely enhanced on the measures compared by percent change scores due to the rectangular shape of their distribution.

The final methodological consideration is the possibility of a Type II error: the likelihood that light threshold training was not conducted long enough to obtain an effect on more of the experiment's measures. Closely related is the question of "What effect would more training have?" To deal with these questions we need to compare this study with those of others who have conducted similar research on light threshold training (Balliet et al., 1983; Zihl, 1981b; Zihl & von Cramon, 1979c; Zihl & von Cramon, 1982).

Zihl and von Cramon (1979c) studied 12 subjects with visual field defects. They administered 15 to 20 threshold trials each session and the sessions lasted approximately one hour. The number of sessions ranged roughly from 10 to 30, based on the reported number of trials (number of trials per subject ranged from 180 to 560). They reported visual field imprövments ranged from 1° to 27°, and the improvement was observed within the first 3 to 8 training sessions for all subjects. Later studies (Zihl, 1981b; Zihl & von Cramon, 1982) reported up to 2130 trials per patient. However, their results were not strikingly different, despite many more sessions. For example, Zihl & von Cramon (1979c) reported a mean increase across all subjects of 10.3° , Zihl (1981b) reported a mean increase of 9.2°, and Zihl & von Cramon

(1982) reported an increase of 7° in peripheral field areas and 3.5° in central field areas.

Balliet et al. (1983) studied 12 subjects with field defects due to occipital lesions demonstrated on CT scans. They administered approximately 200 threshold trials per session. The sessions were given on a 2-to 5-day-per-week basis and the total number was determined "by the availability and motivation of the subjects." The sessions were given over a 2-to 11-month period. Initially, a chin rest was used and visual field expansion was observed. However, it was also noted that subjects were making many small head movements. They began the study again using a full impression bite bar which effectively limited head movements. Small deviations of fixation were still possible and this required close monitoring. With the bite bar condition, Balliet et al. (1983) found little improvement in field size following training. They administered an average of 5927 threshold trials and found a mean improvement of less than 1° (0.69°) for the light threshold training method.

In comparison, the research presented in this dissertation extensively studied 9 subjects with field defects. The training sessions lasted approximately 90 minutes and each subject received 100 threshold measures (50 in each eye). Subject L1 was the only exception to this as he received training in only his right eye. The Early treatment group received a total of 1200 trials and the Late treatment group received 600 trials. Given that studies reporting improvement do so within the first 3 to 8 sessions (or the first 160 threshold trials), it seems unlikely that a Type II error accounts for the results of the dissertation research.

Implications

Zihl and von Cramon (1979c; 1982) and Zihl (1981b) reported their subjects' subjective impressions of improved vision. Basically all subjects reported at least some improvement. None reported a decline in visual abilities. Similarily, Balliet et al. (1983), despite lack of objective evidence for field improvement, observed that 4 subjects reported expanded fields, 2 were unsure, and 6 reported no change. This suggested that subjects were inaccurate in providing subjective reports of improved vision. The study reported in this dissertation provided some information on this issue. Initially all 9 subjects were asked to rate their "overall" visual abilities on a scale from 1 to 10, with 10 being "the best your vision has ever been." At the end of the study they were asked to rate their vision again on the same 10-point scale. First, they were asked to rate their current abilities as of the end of the study. They were then asked to rate where they thought their vision was at the beginning. Table 8 presents these judgments as well as the percent change in the ratings. The final column shows

TABLE 8

Subjective Judgment of Vision

Subject	Pre-study Rating	Post Hoc Ratings Initial	Post Hoc Ratings Post-Study	Ratings % Change	Target Detection % Change [a]
E1	9	7.5	9	15%	5%
E2	5	3	3	0%	1%
E3	5	5	7	20%	16%
E4	5	4	6	20%	18%
L1	2	5	5	0%	10%
L2	5	7	8	10%	9%
L3	7	6	8	20%	11%
L4	4	5	6	10%	8%
L5	7	8	8	0%	7%
Means of Columns	5.4	5.6	6.6	10.5%	9.4%

Table 8. Subjects' ratings of their vision on a 10-point scale with 10 being "the best your vision has ever been," are presented above.
[a] This measure is the difference between the last baseline measure and the final assessment of light target detection averaged for both visual fields.

the percent improvment for each subject on static light detection based on the last baseline measure compared to the final measure at the end of the study. The bottom row presents the means for these figures and indicates that subjects judged that they improved by approximately 10%.

Insert Table 8

Interestingly, the target detection task also indicated this. Furthermore, those subjects who judged that they had improved the most (E3, E4, and L3) were the same subjects who did improve most on the target detection task. This suggests that subjects were able to report subjective improvement with some degree of accuracy. This obviously did not generalize to all areas of visual ability assessed in this study.

The finding of improved static target detection (Auto Perimeter) with no improvement observed on kinetic target detection (Goldmann Perimeter) may have implications for those who have suggested that subcortical regions are responsible for recovery of visual functions (Zihl & von Cramon, 1979c). It was pointed out in Chapter 1 that there may be two visual systems, with the striate cortex providing information on recognition and the subcortical superior colliculus system giving information on movement and location (Schneider, 1969). If this be so, one should expect improvement in detecting moving targets more so than static targets. Given the outcome of the study reported in this dissertation, where static target detection improved and kinetic target detection did not, it seems unlikely that the improvement observed was due to the superior collicular visual system.

The subjects for this study were in many ways selfselected and yet presented a heterogeneous and medically complex group. This is more the rule than the exception for these types of clinical studies. When one obtains clear treatment effects, generalizations to other patient populations is difficult. One can argue that due to the treatment being effective with the initial heterogeneous group the results are more likely to hold for other groups. Yet other groups may have lesions and medical conditions which represent such individual differences that it is unlikely to observe improvement with similar treatment. This dissertation has followed the former reasoning, rather than the latter.

Addressing the question initially presented in Chapter 1 (page 23) regarding improving vision with training, it seems that the answer is, for practical applications, generally "no." There was no evidence that training improved any of several measures of skills thought to assess elements of "everyday" vision. The degree of improvement found on the static light target task (roughly 10% improvement across all subjects) compared well with the results of Zihl and von

Cramon (1979c; 1982). That improvement did occur, even if due to developing compensatory strategies with practice, may have provided some patients with encouragement. However, the realistic benefits of this and similar training programs of the visual system, based on the results of this study, appeared very limited. The patient who reported the most improvement (E4), and who improved the most on static target detection, seemed to gain most from the psychological support and knowledge that he was "doing something" for his visual defect.

Further research might approach this area with the understanding that subjects will develop strategies with practice and then attempt to determine which strategies are most effective. This could enhance rehabilitative efforts currently being directed towards cognitive retraining of brain-injured patients with visual field deficits.

SUMMARY

This study attempted to evaluate light threshold training by documenting improved vision-dependent behaviour in patients with visual field defects.

Random group assignment resulted in an obvious performance level difference, in favor of the Early treatment group. Percent change scores were utilized to evaluate group differences. No significant group differences were documented using this method of analysis.

Evaluation of single-case data revealed improvement on two experimental measures. However, there were no apparent practical benefits from these improvements.

Generally, patients rated an overall increase of roughly 10% in their vision. This compared well with the light target detection task and prior research (Zihl & von Cramon, 1979c; 1982).

The most conservative interpretation of the results is that the threshold training enhanced detection strategies developed during the first few sessions of threshold training.

Further research should attempt to focus on these strategies and evaluate which are most effective.

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APPENDIX A

Contains samples of interviews, visual assessment tasks, and response sheets.

INTERVIEW FOR STUDY ON VISION

NAME________________________ SEX____ DATE____________ AGE______ D.O.B.__________

HIGHEST GRADE____ RACE__________ MRN______

LATERAL DOMINANCE (By History)____

OCCUPATION____

GLASSES (Type)______________________________________ CONTACT LENS______________

KNOWLEDGE OF VISUAL PSYCHOPHYSICS____

HISTORY OF EYE PROBLEMS____

AVERAGE INCOME (Household): ____

<u>PRESENTING COMPLAINT</u>:

<u>PATIENT'S DESCRIPTION OF ILLNESS</u>:

<u>PATIENT'S DESCRIPTION OF VISION</u>: (Include approx. date of onset for field cut):

<u>OTHER:</u>

Current Medications:

Past Medical History:

Previous Hospitalizations:

Previous Operations:

Headaches:

Injuries;

Sensory (Visual, Auditory, Tactile, Taste, Smell):

Motor:

Seizure:

Psychological (Personality, Substance abuse, Hallucinations, Depression, etc.):

Speech:

Memory:

Infections:

Diabetes:

Metabolic:

Vascular:

Febrile:

Drug Reactions:

Further Questions:

Does anything bother you about your vision?

Does anthing else seem unusual or odd about your vision?

Does your vision stay the same or does it change frequently from day to day?

How does your eyesight affect your daily life?

What type of thigs do you currently read?

How much time do you spend reading each day? (And is this different from before?):

Ona scale of one to ten (with ten being the best and one being the worst) how would you rate your current visual abilities compared to your eyesight prior to your visual field defect?

1 2 3 4 5 6 7 8 9 10

OTHER COMMENTS:

MEDICATION AND DIAGNOSTIC TESTING HISTORY

Patient Name ______________ MRN ______________ Date ______________

Referring Physician ______________ Research ID ______________

A. Phenothiazines — Dose/ Duration

- Thorazine ______
- Mellaril ______
- Prolixin ______
- Stelazine ______
- Haldol ______
- Navane ______
- Loxitane ______
- Trilafon ______
- Moban ______
- Serentil ______

B. Antidepressants — Dose/Duration

- Lithium ______
- Sinequan ______
- Triavil ______
- Elavil ______
- Parnate ______
- Ludiomil ______
- Tofranil ______
- Nardil ______
- Norpramin(e) ______
- Persamine ______
- Adapin ______
- Vivactyl ______
- Aventyl ______

C. Anti-Anxiety

- Dalmane ______
- Benadryl ______
- Atarax ______
- Vistaril ______
- Librium ______
- Valium ______
- Tranxene ______
- Inderal ______

D. Anticonvulsants

- Dilantin ______
- Depakene ______
- Tegretol ______
- Phenobarbital ______
- Mysoline ______
- Clonazepam ______

E. Others

______ ______

______ ______

______ ______

______ ______

F. CT Scan Results: ______________

____

G. EEG Results: ______________

Name ______________________

Date ______________________

Circle the best answer:

1 STRONGLY DISAGREE

2 DISAGREE

3 NOT SURE/ NEITHER AGREE NOR DISAGREE

4 AGREE

5 STRONGLY AGREE

1. My visual difficulties are due to my needing new glasses: 1 2 3 4 5
2. I notice that I seem to bump into things more often now: 1 2 3 4 5
3. My visual problems are because it is always too dark: 1 2 3 4 5
4. Reading has recently become very difficult for me: 1 2 3 4 5
5. The reason I don't read as well as I could is because the print isn't large enough: 1 2 3 4 5
6. Since my illness, I have not been able to drive because of my poor vision: 1 2 3 4 5
7. If it were only lighter in the room, I would have no visual problems: 1 2 3 4 5
8. I now have trouble walking in busy hallways because I seem to bump into people who I don't see until it is too late: 1 2 3 4 5
9. There is nothing wrong with my vision that a good nights sleep won't cure: 1 2 3 4 5
10. I have never had problems with my vision: 1 2 3 4 5
11. My vision is the reason I no longer read the newspaper: 1 2 3 4 5
12. I often have problems during a meal or dressing because of my eyesight: 1 2 3 4 5
13. My problems with my vision are most noticable when I have to see things out of the corners of my eyes (or at the extreme edge of my field of vision): 1 2 3 4 5
14. The reason I don't see as well as I could is because someone is holding something dark over one of my eyes: 1 2 3 4 5
15. I do not see as well as I could before: 1 2 3 4 5
16. I do not bump into things very often: 1 2 3 4 5
17. I have problems keeping my place in the phone book whenever I look up a number. I do not remember: 1 2 3 4 5

18. Some of my visual problems are due to the lighting used in this room: 1 2 3 4 5

19. I find that television is now more difficult to watch because of my visual problems: 1 2 3 4 5

20. Making a phone call is difficult now because not all the numbers are on the dial: 1 2 3 4 5

FINAL INTERVIEW NAME______________

How would you describe your vision prior to this study?

How would you describe it now?

Did you ever notice anything unusual occurring in your area of poor vision?

How much time do you spend reading p· · day and do you feel this is a change?

On a scale from 1 - 10 (with 10 being the best) where would you place your current vision? Is this different from when you first started this study/ (rank your prior vision from 1 - 10)?

In your own words describe this study as you understand it:

What, if any, were your strategies for doing welll on the various tests?

Did you attempt any "practice" on your own or while at home during this study?

Any comments:

CARD 1

NINETY-FIVE	THIRTY-NINE	TWENTY-SEVEN	NINETY-TWO	SEVENTY-FIVE
EIGHTY-FIVE	SEVENTY-ONE	EIGHTY-EIGHT	EIGHTY-ONE	FIFTY-ONE
SIXTY-NINE	NINETY-SIX	EIGHTY-SIX	SEVENTY-EIGHT	SIXTY-ONE
SIXTY-FIVE	TWENTY-FOUR	TWENTY-SIX	FORTY-ONE	SEVENTY-TWO

CANCELLATION (H)

NAME________________

DATE________________ TEST#_____

B H D F C H C F H G I H C H I H B D A H C F B H D E H D A F H I C H F H B A F H E H F H C B D H F G H E

H E G H F E H D H F C B F H A D H C E H I H G D H G E B H E G H I H C H E H F C I H E B H G F D H B E H

H B H A E H B H C F A H F H G H C G D H C B A H G D E H C H B E H D G H D A F H B I F H E B H D H E H G

H D G A H C H F B H A F H E B F H C D H F H G E H B H D H F A C H C H F D I H C B I H B H A C H D H F B

E H B H G B I H C E H A F H I H E B H G F B H F A H E B G H G F E H D B H B H C F H A D C H E I H F H G

H D C B H E D G H A D F H B H I G E H G H D E H C G H D H E B A H F B H C D A H G B H C H D F H C A I H

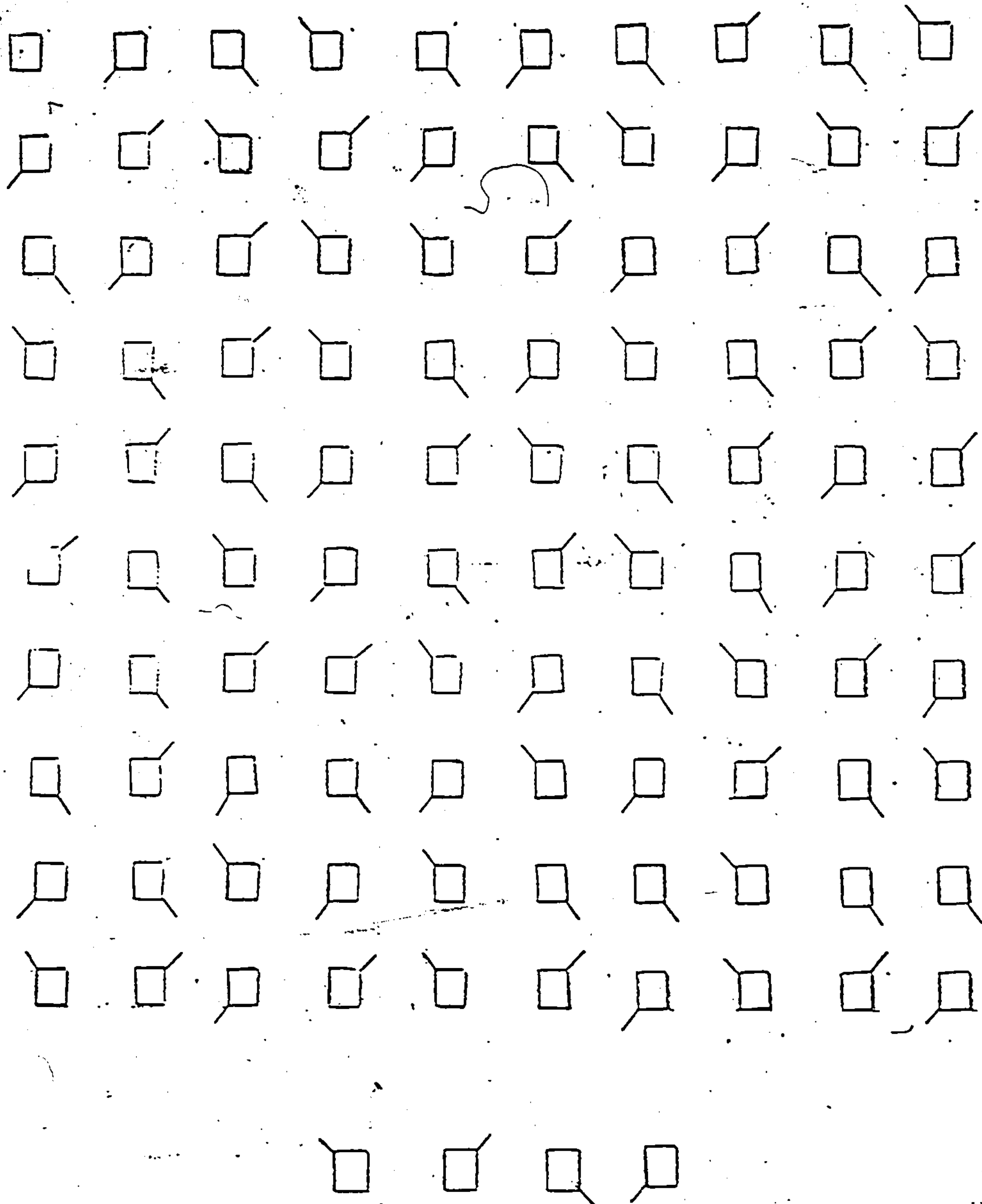
TIME________________

Errors: L____/R_____

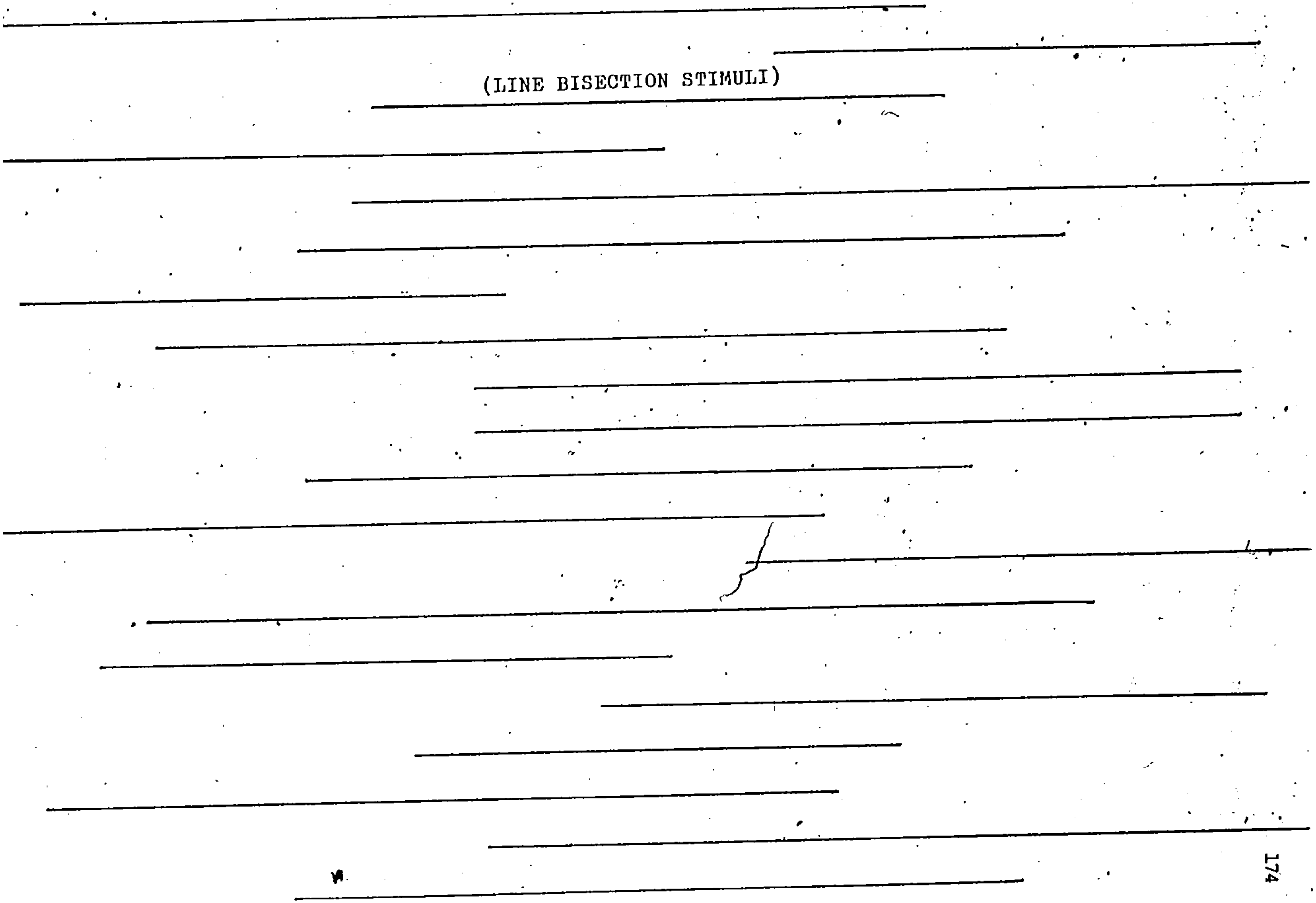
(BOX SEARCH)

NAME ________________

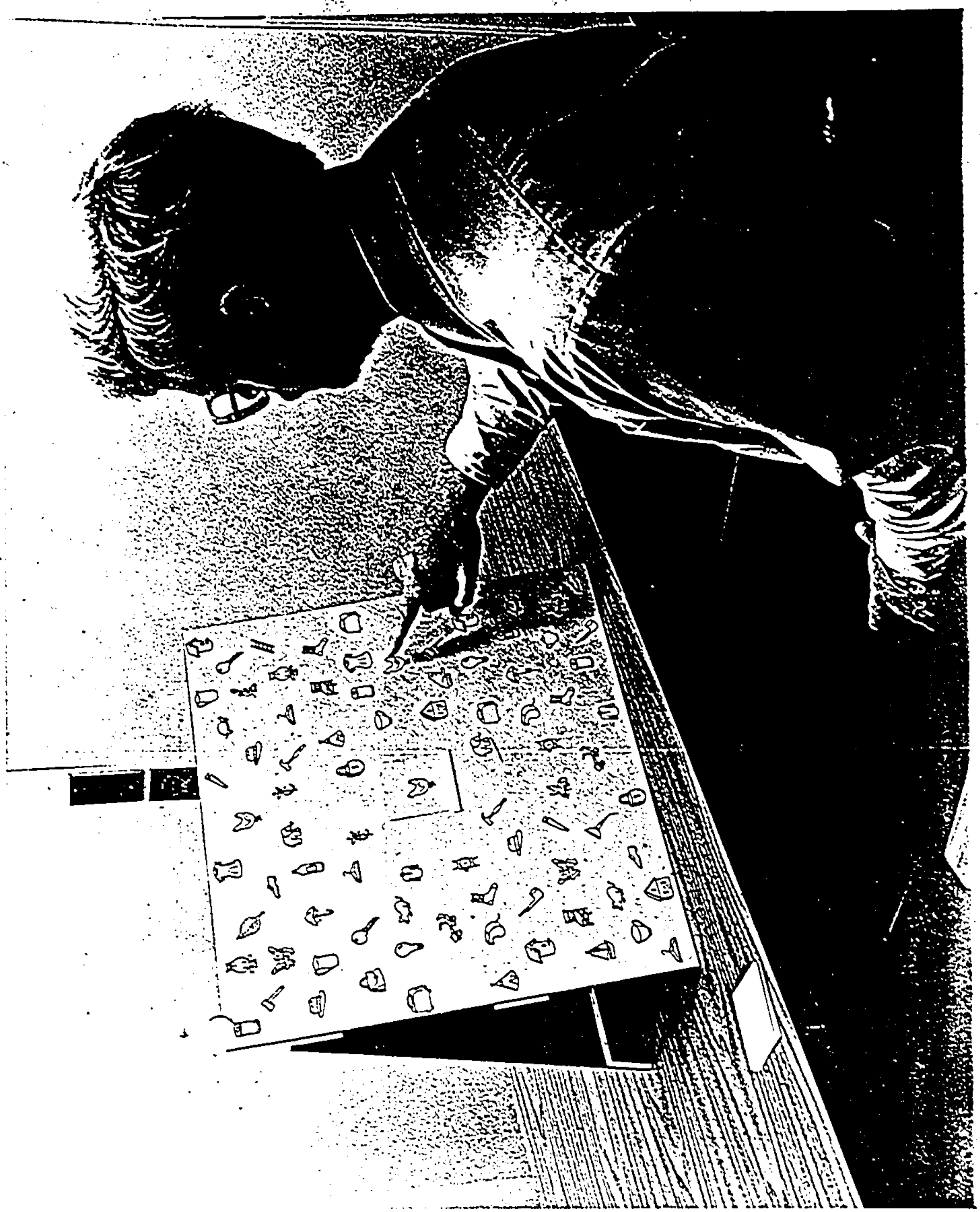
DATE __________



(LINE BISECTION STIMULI)



Visual Search Board



VISUAL SEARCH TASK

PSYCHOLOGY DEPARTMENT

Revised - July 1977

NAME: ______________ 176

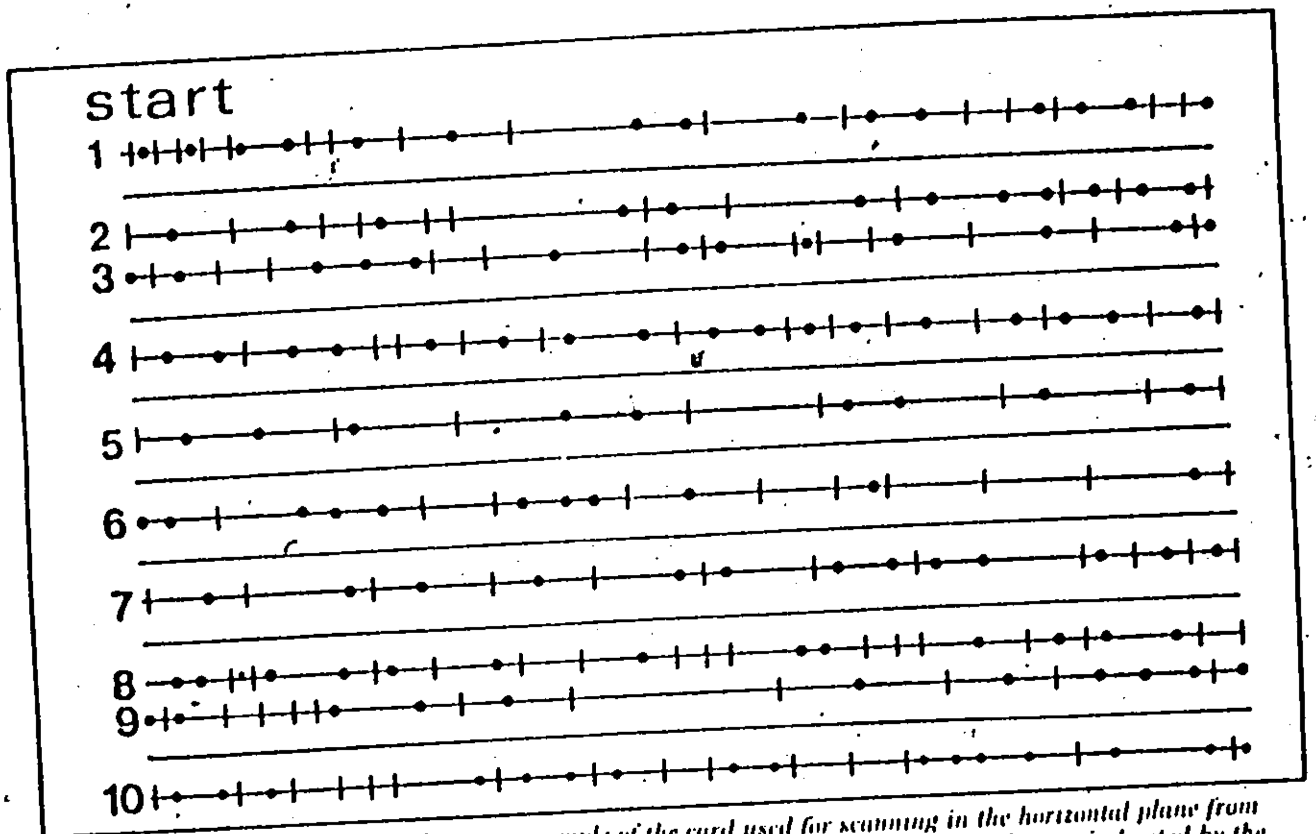
DATE: ______________ FIELD DEFECT: ________

SEX: ______ HAND: ______ AGE: ______

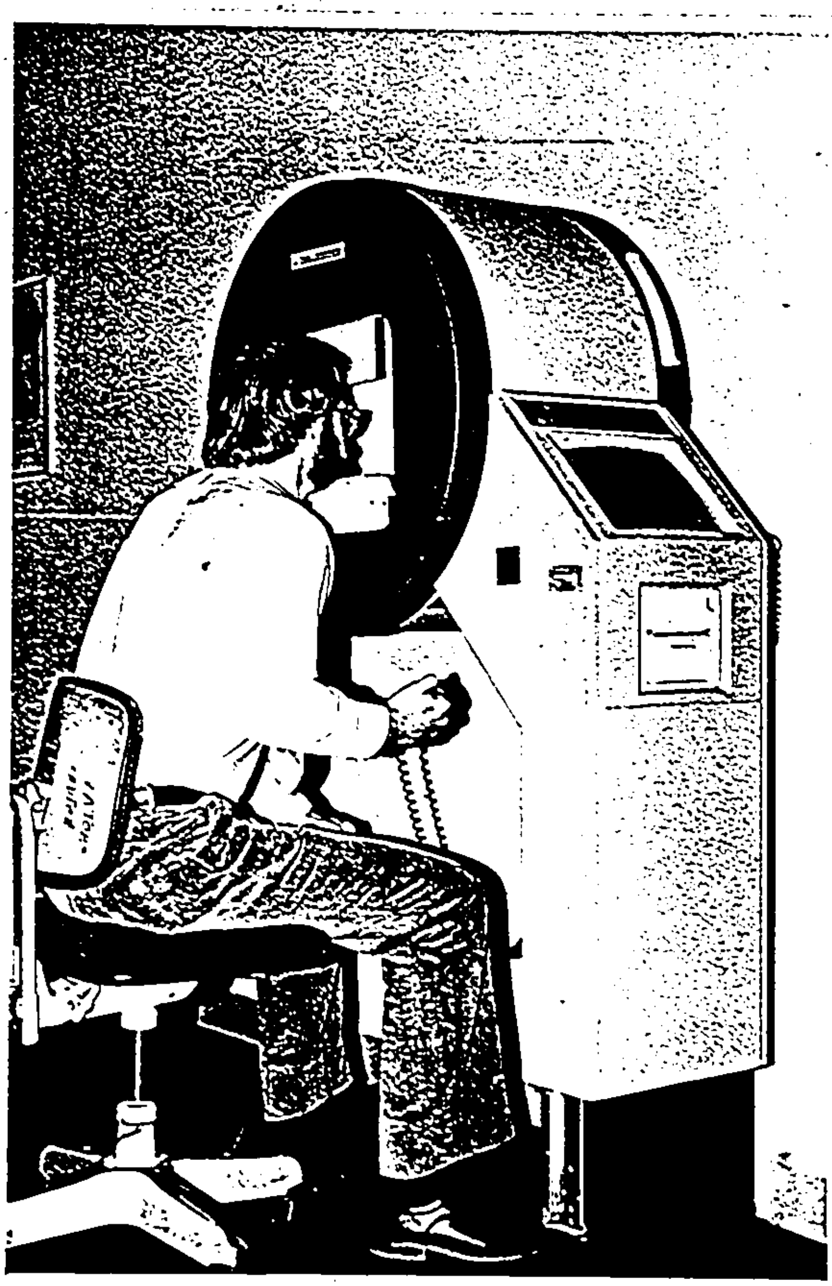
		UL	LL	UR	LR
1.	Butterfly	*	*		
2.	Frog				*
3.	Hat	*	*	*	
4.	Sailboat		*		
5.	Birdhouse		*	*	*
6.	Telephone			*	
7.	Oilcan		*		
8.	Umbrella	*			*
9.	Hanger	*	*	*	
10.	Purse	*			
11.	Ladder			*	
12.	Turtle			*	*
13.	Leaf	*			
14.	Shoe	*	*		*
15.	Sock		*	*	*
16.	Teapot				*
17.	Spool	*		*	*
18.	Teepee		*	*	
19.	Toaster	*		*	*
20.	Mouse	*	*		*

	LEFT	RIGHT
Preference Score	= ____ + ____ = -5 = [ ]	= ____ + ____ = -5 = [ ]
Mean Response Time	= ____ + ____ = [ ]	= ____ + ____ = [ ]

VISUAL SCANNING TEST



Dots and dashes task. This is an example of the card used for scanning in the horizontal plane from left to right. Subjects were asked to count the number of dots or dashes on a particular line as indicated by the experimenter.



APPENDIX B

Contains probability levels for all outcomes of the split middle binomial test for significance, list of first order hyperbolic function (1/X), and compares raw data for the repeating measures to first order hyperbolic projected curve.

Significance Levels

Significance levels for the Early treatment group (maximum possible number of data points above or below projected curve = 14) are presented below. The top number is the number of treatment data points improved from the baseline projected curve. The bottom number is the probability value for a one-tailed test of significance.

14	13	12	11	10	9	8	7	6	5	4	3	2	1
.0001	.001	.01	.03	.09	.21	.4	.61	.79	.91	.97	.99	.99	.99

Significance levels for the Late treatment group (maximum possible number of treatment data points above or below projected curve = 7) are presented below. The top number is the number of treatment data points improved from the projected curve. The bottom number is the probability value for a one-tailed test of significance.

7	6	5	4	3	2	1	0
.01	.06	.23	.50	.77	.94	.99	.999

Values for 1/X as a function of X

Below are the values for 1/X and represent the first order hyperbolic function where X is the experimental session number. The 1/X values are used for the regression equation. This allows the projection of a hyperbolic curve through the treatment sessions based on data from the baseline sessions.

X values	1/X values
1	1.0
2	0.5
3	0.33
4	0.25
5	0.20
6	0.167
7	0.143
8	0.125
9	0.111
10	0.1
11	0.09
12	0.083
13	0.077
14	0.071
15	0.067
16	0.063
17	0.059

Raw Data for **Auto Perimeter**

Raw data compared to projected curves :

Subject:E1: AUTO PERIMETER
(Percent of light targets detected)

	Left Visual Field		Right Visual Field	
Session No.	Raw Score	Curve Score	Raw Score	Curve Score
1	77.6%	77.9%	86.9%	87.1%
2	83.3%	82.3%	88.8%	87.9%
3	83 %	83.8%	87.5%	88.2%
4	75.3%	84.5%	86.9%	88.3%
5	79.5%	84.9%	89.7%	88.4%
6	81.4%	85.2%	89.4%	88.4%
7	69.2%	85.5%	84.6%	88.5%
8	76.9%	85.6%	91.4%	88.5%
9	83.7%	85.7%	88.5%	88.5%
10	87.5%	85.8%	95 %	88.5%
11	77.2%	85.9%	92.6%	88.6%
12	89.8%	86 %	92.3%	88.6%
13	84 %	86 %	88.5%	88.6%
14	75.3%	86.1%	83.3%	88.6%
15	85.6%	86.1%	90.4%	88.6%
16	78.5%	86.2%	88.1%	88.6%
17	86.9%	86.2%	93 %	88.6%

Subject:E2:

1	88.1%	88 %	34.3%	34.3%
2	89.4%	89.7%	40.7%	40.9%
3	90.4%	90.2%	43.3%	43.1%
4	91.7%	90.5%	41.7%	44.3%
5	90.7%	90.6%	46.2%	44.9%
6	91 %	90.7%	44.6%	45.4%
7	91 %	90.8%	46.2%	45.7%
8	90.7%	90.9%	45.2%	45.9%
9	89.1%	90.9%	47.4%	46.1%
10	90.4%	91 %	46.5%	46.3%
11	89.7%	91 %	45.5%	46.4%
12	87.5%	91 %	45.2%	46.5%
13	88.8%	91 %	45.2%	46.6%
14	89.7%	91.1%	42.9%	46.6%
15	88.1%	91.1%	45.2%	46.7%
16	88.5%	91.1%	43.6%	46.7%
17	87.8%	91.1%	48.7%	46.8%

Subject:E3:	Left	Field	Right	Field
1	73.1%	73.1%	4.2%	3.8%
2	77.6%	77.5%	5.8%	7.5%
3	78.9%	78.9%	9.9%	8.7%
4	77.2%	79.7%	11.9%	9.3%
5	83 %	80.1%	24.7%	9.6%
6	82.4%	80.4%	20.5%	9.9%
7	83.7%	80.6%	14.1%	10.1%
8	90.4%	80.8%	18 %	10.2%
9	92.3%	80.9%	29.8%	10.3%
10	90.4%	81 %	18.9%	10.4%
11	90.7%	81.1%	26.9%	10.4%
12	87.8%	81.2%	24.7%	10.5%
13	93.6%	81.2%	34.9%	10.5%
14	93 %	81.3%	40.1%	10.6%
15	92 %	81.3%	34.6%	10.6%
16	93.9%	81.3%	36.5%	10.6%
17	91.4%	81.4%	29.5%	10.7%

Subject:E4:				
1	16.4%	16.5%	82.7%	82.5%
2	15.1%	14.7%	76.6%	77.4%
3	13.8%	14.1%	76.3%	75.7%
4	18.6%	13.8%	77.6%	74.9%
5	19.9%	13.6%	84.9%	74.3%
6	22.8%	13.5%	90.7%	74 %
7	22.1%	13.4%	93.6%	73.8%
8	23.4%	13.4%	91.7%	73.6%
9	26 %	13.3%	93.6%	73.4%
10	29.5%	13.3%	92 %	73.3%
11	25.6%	13.2%	94.2%	73.2%
12	30.5%	13.2%	94.6%	73.2%
13	29.5%	13.2%	93.9%	73.1%
14	30.1%	13.2%	98.1%	73 %
15	32.1%	13.2%	93.9%	73 %
16	30.5%	13.1%	95.8%	73 %
17	31.4%	13.1%	95.2%	72.9%

Subject:L1:	Left	Field	Right	Field
1	30.3%	32.8%	77.5%	76.3%
2	30.9%	31.7%	71.9%	75.5%
3	39.5%	31.4%	75.6%	75.2%
4	36.8%	31.2%	77.5%	75.1%
5	34.9%	31.1%	74.4%	75 %
6	24.3%	31.1%	72.5%	74.9%
7	31.6%	31 %	77.5%	74.9%
8	27.6%	31 %	75 %	74.9%
9	26.3%	30.9%	73.8%	74.8%
10	30.9%	30.9%	75.6%	74.8%
11	39.5%	30.9%	73.8%	74.8%
12	29.6%	30.9%	79.4%	74.8%
13	45.4%	30.9%	85.6%	74.8%
14	50.7%	30.9%	83.1%	74.8%
15	41.4%	30.9%	80.6%	74.8%
16	36.2%	30.8%	83.8%	74.8%
17	43.4%	30.8%	82.5%	74.7%

Subject:L2:				
1	70.2%	71.1%	94.9%	94.4%
2	74.4%	73 %	95.2%	95.2%
3	73.1%	73.6%	94.6%	95.5%
4	74.7%	73.9%	93.6%	95.6%
5	76.3%	74.1%	95.5%	95.7%
6	75.6%	74.2%	95.8%	95.8%
7	73.7%	74.3%	96.2%	95.8%
8	72.8%	74.3%	97.4%	95.8%
9	74 %	74.4%	96.5%	95.9%
10	72.4%	74.4%	95.8%	95.9%
11	71.8%	74.5%	96.5%	95.9%
12	76 %	74.5%	96.5%	95.9%
13	74 %	74.5%	96.2%	95.9%
14	73.7%	74.5%	95.5%	95.9%
15	77.3%	74.6%	96.2%	95.9%
16	75.3%	74.6%	96.2%	95.9%
17	85.3%	74.6%	100 %	95.9%

Subject:L3	Left	Field	Right	Field.
1	4.8%	4.95%	66.7%	70.9%
2	4.5%	7.1%	86.2%	81.2%
3	13.1%	7.8%	91.7%	84.7%
4	8.7%	8.1%	89.4%	86.4%
5	7.7%	8.3%	86.9%	87.4%
6	7.4%	8.6%	87.8%	88.1%
7	7.4%	8.6%	86.2%	88.6%
8	8.7%	8.6%	84.9%	89 %
9	9 %	8.7%	88.5%	89.3%
10	8 %	8.7%	86.9%	89.5%
11	5.8%	8.8%	91.3%	89.7%
12	15.7%	8.8%	95.5%	89.9%
13	16.7%	8.8%	96.8%	90 %
14	21.2%	8.9%	97.1%	90.1%
15	20.5%	8.9%	97.4%	90.2%
16	23.4%	8.9%	97.1%	90.3%
17	20.2%	8.9%	96.8%	90.4%

Subject:L4:

1	89.4%	88.8%	26.3%	26.4%
2	88.1%	89.2%	28.5%	27.6%
3	88.8%	89.3%	26.3%	28 %
4	89.4%	89.3%	28.5%	28.2%
5	88.1%	89.4%	27.2%	28.3%
6	89.7%	89.4%	29.5%	28.4%
7	91 %	89.4%	30.8%	28.4%
8	89.1%	89.4%	26.9%	28.5%
9	89.7%	89.4%	28.9%	28.5%
10	89.7%	89.4%	27.9%	28.6%
11	89.4%	89.5%	29.2%	28.6%
12	97.8%	89.5%	33.3%	28.6%
13	98.1%	89.5%	35.6%	28.6%
14	99 %	89.5%	36.2%	28.6%
15	98.1%	89.5%	35.3%	28.6%
16	98.7%	89.5%	35.3%	28.6%
17	99.4%	89.5%	34:6%	28.7%

Subject:L5:	Left	Field	Right	Field
1	87.2%	86.9%	89.4%	89.9%
2	89.1%	88.9%	91.7%	90.5%
3	88.1%	89.6%	90.7%	90.7%
4	90.1%	90 %	89.4%	90.8%
5	90.1%	90.2%	91.7%	90.9%
6	89.7%	90.3%	91.7%	90.9%
7	93.6%	90.4%	93.3%	91 %
8	86.5%	90.5%	91.4%	91 %
9	92 %	90.5%	86.4%	91 %
10	91.4%	90.6%	92 %	91 %
11	89.7%	90.6%	91.7%	91 %
12	98.4%	90.6%	94.9%	91 %
13	97.8%	90.7%	96.5%	91 %
14	97.8%	90.7%	98.1%	91 %
15	99 %	90.7%	98.4%	91.1%
16	98.7%	90.7%	97.1%	91.1%
17	98.7%	90.7%	98.1%	91.1%

Raw Data for **Two-Point Sensory Thresholds:**

Raw data compared to projected curves:

Two-Point Thresholds in Millimeters:

Subject E1:

	Left Hand Data		Right Hand Data	
Session	Score	Curve	Score	Curve
1	12	12	6	6
2	8	10	7	7
3	10	9	8	8
4	7	9	8	8
5	7	8	6	8
6	9	8	6	8
7	6	8	4	8
8	6	8	6	8
9	7	8	7	8
10	7	8	8	8
11	6	8	8	8
12	7	8	8	9
13	6	8	5	9
14	6	8	4	9
15	6	8	6	9
16	5	8	4	9
17	6	8	3	9

Two-Point Threshold Data Continued:

Subject E2: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	10	10	6	6
2	6	8	8	8
3	8	7	9	9
4	8	7	9	9
5	6	6	5	10
6	8	6	7	10
7	5	6	8	10
8	6	6	8	10
9	7	6	7	10
10	8	6	4	10
11	7	6	8	10
12	6	6	5	10
13	8	6	8	10
14	6	6	6	10
15	4	6	3	10
16	7	6	4	10
17	4	6	5	10

Subject E3: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	7	7	8	8
2	7	7	7	9
3	7	7	11	10
4	8	7	8	10
5	2	7	4	10
6	6	7	10	10
7	9	7	10	10
8	14	7	10	10
9	2	7	8	10
10	3	7	14	10
11	4	7	9	10
12	3	7	2	10
13	10	7	3	10
14	6	7	6	10
15	5	7	8	10
16	3	7	6	10
17	6	7	8	10

Two-Point Threshold Data Continued:

SubjectE4: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	8	8	7	7
2	7	7	6	7
3	6	6	8	7
4	8	6	14	7
5	6	6	10	7
6	8	6	8	7
7	8	6	5	7
8	5	6	8	7
9	6	6	6	7
10	8	6	6	7
11	8	6	5	7
12	6	6	8	7
13	8	6	6	7
14	8	6	5	7
15	8	6	4	7
16	8	6	7	7
17	8	6	6	7

Subject L1: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	8	8	10	11
2	11	9	9	8
3	7	9	7	8
4	8	10	9	7
5	12	10	9	7
6	11	10	7	7
7	10	10	7	7
8.	9	10	5	7
9	9	10	5	7
10	9	10	6	7
11	12	10	8	7
12	8	10	6	6
13	10	10	6	6
14	9	10	8	6
15	7	10	7	6
16	10	10	6	6
17	6	10	5	6

Two-Point Threshold Continued:

Subject:L2: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	9	9	6	7
2	8	9	11	8
3	12	9	9	8
4	8	9	6	9
5	10	9	7	9
6	7	9	7	9
7	7	9	8	9
8	11	9	10	9
9	9	9	8	9
10	12	9	12	9
11	6	10	8	9
12	8	10	11	9
13	9	10	7	9
14	12	10	8	9
15	2	10	12	9
16	12	10	8	9
17	9	10	6	9

Subject:L3: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	8	9	6	5
2	12	9	5	7
3	7	9	10	7
4	6	9	6	8
5	6	9	6	8
6	8	9	7	8
7	10	9	10	8
8	7	9	8	8
9	10	9	8	8
10	11	9	9	8
11	13	9	10	8
12	11	9	5	8
13	6	9	6	8
14	9	9	9	8
15	9	9	11	8
16	10	9	7	8
17	6	9	10	8

Two-Point Threshold Data Continued:

Subject:L4: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	10	9	5	6
2	9	8	8	6
3	5	8	5	6
4	6	8	5	6
5	8	8	6	6
6	7	8	5	6
7	8	8	6	6
8	7	8	6	6
9	10	8	5	6
10	12	8	7	6
11	8	8	6	6
12	6	8	2	6
13	5	8	6	6
14	6	8	4	6
15	5	8	6	6
16	3	8	5	6
17	8	8	5	6

Subject:L5: Left Hand / Right Hand

Session	Left Hand Score	Left Hand Curve	Right Hand Score	Right Hand Curve
1	8	7	6	6
2	4	6	6	6
3	8	6	5	6
4	5	6	3	6
5	5	5	5	6
6	3	5	8	6
7	6	5	8	6
8	6	5	5	6
9	5	5	5	6
10	6	5	8	6
11	3	5	6	6
12	6	5	6	6
13	6	5	6	6
14	5	5	6	6
15	4	5	5	6
16	8	5	6	6
17	3	5	6	6

Raw data (in kilograms) for Grip Strength scores compared to projected curve scores:

Subject:E1: Left Hand / Right Hand

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	35.5	35.4	33.5	33.4
2	34.5	34.8	31.5	31.8
3	35.0	34.7	31.5	31.3
4	30.5	34.6	29.5	31.0
5	28.0	34.6	29.5	30.8
6	33.5	34.5	32.5	30.7
7	32.5	34.5	30.5	30.7
8	31.5	34.5	32.5	30.6
9	30.0	34.5	31.0	30.6
10	33.0	34.5	27.5	30.5
11	32.5	34.5	31.0	30.5
12	34.0	34.5	30.0	30.5
13	31.0	34.5	30.0	30.4
14	31.0	34.4	27.5	30.4
15	32.5	34.4	28.5	30.4
16	29.0	34.4	29.0	30.4
17	31.5	34.4	27.0	30.4

Subject:E2: Left Hand / Right Hand

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	35.5	35.6	40.5	41.6
2	40.0	39.8	47.5	43.2
3	41.0	41.2	40.5	43.8
4	43.0	41.9	48.5	44.0
5	43.0	42.3	52.0	44.2
6	43.5	42.6	50.0	44.3
7	43.0	42.8	50.0	44.4
8	41.5	42.9	45.0	44.4
9	40.0	43.0	44.5	44.5
10	40.0	43.1	46.5	44.5
11	41.5	43.2	39.5	44.5
12	45.5	43.3	49.5	44.5
13	39.5	43.3	42.0	44.6
14	44.5	43.4	50.5	44.6
15	39.5	43.4	49.5	44.6
16	42.0	43.5	50.0	44.6
17	41.5	43.5	49.0	44.6

Grip Strength Data Continued:

Subject:E3

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	41.0	40.4	43.0	41.7
2	34.0	36.5	38.0	37.2
3	37.0	35.2	36.0	35.6
4	42.5	34.5	43.5	34.9
5	39.5	34.1	42.0	34.5
6	41.0	33.9	38.5	34.2
7	34.0	33.7	41.0	33.9
8	34.5	33.6	35.0	33.8
9	33.0	33.4	40.0	33.6
10	33.5	33.4	38.5	33.5
11	35.5	33.3	42.0	33.5
12	34.0	33.2	35.0	33.4
13	32.5	33.2	36.5	33.3
14	31.0	33.1	38.0	33.3
15	34.5	33.1	36.5	33.2
16	34.5	33.1	35.5	33.2
17	34.5	33.0	33.0	33.2

Subject:E4:

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	51.5	50.8	57.5	58.2
2	49.5	52.4	62.0	59.5
3	55.0	52.9	58.0	59.9
4	52.0	53.1	58.0	60.1
5	52.0	53.3	58.0	60.2
6	62.5	53.4	64.5	60.3
7	56.0	53.5	57.0	60.4
8	55.0	53.5	59.0	60.4
9	62.5	53.6	68.0	60.5
10	57.0	53.6	58.0	60.5
11	51.0	53.6	57.0	60.5
12	57.0	53.7	55.0	60.6
13	60.0	53.7	68.0	60.6
14	64.5	53.7	70.5	60.6
15	60.5	53.7	70.0	60.6
16	57.0	53.7	61.0	60.6
17	60.0	53.7	64.0	60.6

Grip Strength Data Continued:

Subject L1: Left Hand / Right Hand

Session	Raw Score (Left Hand)	Curve (Left Hand)	Raw Score (Right Hand)	Curve (Right Hand)
1	17.5	16.9	29.5	29.0
2	18.5	20.4	30.5	31.8
3	23.0	21.6	33.0	32.7
4	21.5	22.2	32.0	33.2
5	22.0	22.6	34.0	33.5
6	24.5	22.8	37.0	33.7
7	21.0	23.0	30.0	33.8
8	24.5	23.1	35.5	33.9
9	26.0	23.2	38.0	34.0
10	20.5	23.3	30.0	34.0
11	22.5	23.3	33.0	34.1
12	25.0	23.4	36.0	34.1
13	24.0	23.4	34.5	34.2
14	23.0	23.5	33.5	34.2
15	21.0	23.5	31.5	34.2
16	22.0	23.5	35.5	34.2
17	22.0	23.6	37.0	34.3

Subject L2:

1	26.0	27.5	31.0	30.1
2	32.5	29.9	33.5	33.4
3	36.0	30.7	36.0	34.3
4	27.0	31.1	27.5	34.7
5	29.0	31.4	26.0	34.9
6	31.0	31.5	41.5	35.1
7	28.5	31.6	32.5	35.2
8	35.5	31.7	31.5	35.3
9	29.0	31.8	38.5	35.4
10	34.5	31.8	36.5	35.5
11	33.5	31.9	35.0	35.5
12	37.5	31.9	43.0	35.6
13	32.5	32.0	36.5	35.6
14	34.0	32.0	37.0	35.6
15	35.0	32.0	39.5	35.6
16	33.0	32.0	40.5	35.7
17	35.0	32.0	39.5	35.7

Grip Strength Data Continued:

Subject L3: Left Hand / Right Hand

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	31.5	30.5	31.0	31.1
2	32.0	31.6	37.5	33.9
3	30.5	32.0	30.5	34.8
4	30.0	32.2	34.0	35.3
5	31.0	32.3	36.0	35.6
6	29.0	32.4	33.0	35.8
7	28.0	32.4	31.0	35.9
8	38.0	32.5	39.0	36.0
9	38.5	32.5	42.5	36.1
10	32.5	32.5	36.0	36.1
11	33.0	32.6	40.0	36.2
12	27.5	32.6	33.0	36.2
13	40.0	32.6	43.0	36.3
14	39.0	32.6	42.0	36.3
15	32.0	32.6	36.0	36.3
16	31.0	32.6	34.0	36.4
17	30.0	32.6	34.5	36.4

Subject:L4:

1	41.0	38.6	43.5	41.3
2	42.0	44.9	43.0	44.1
3	43.0	47.0	39.5	45.0
4	46.0	48.0	42.5	45.4
5	47.0	49.0	42.0	45.7
6	51.0	49.0	50.0	45.9
7	53.0	49.3	51.0	46.0
8	50.0	49.6	45.0	46.1
9	53.0	49.7	51.0	46.2
10	48.5	49.9	44.5	46.3
11	49.0	50.0	45.5	46.3
12	46.0	50.1	46.0	46.4
13	53.0	50.2	53.0	46.4
14	50.5	50.2	47.5	46.4
15	54.5	50.3	48.5	46.5
16	47.0	50.3	48.0	46.5
17	51.0	50.4	53.0	46.5

Grip Strength Data Continued:

SubjectL5: Left Hand / Right Hand

Session	Left Hand Raw Score	Left Hand Curve	Right Hand Raw Score	Right Hand Curve
1	37.0	36.9	39.0	38.7
2	34.5	33.4	37.0	35.7
3	31.0	32.2	32.0	34.7
4	29.5	31.7	33.5	34.2
5	31.0	31.3	34.5	33.9
6	32.0	31.1	31.0	33.7
7	30.0	30.9	33.0	33.6
8	30.0	30.8	32.5	33.5
9	36.5	30.7	39.0	33.4
10	28.0	30.6	33.0	33.3
11	30.0	30.6	31.0	33.3
12	30.5	30.5	32.5	33.2
13	28.5	30.5	31.5	33.2
14	29.0	30.4	29.0	31.1
15	31.0	30.4	31.5	33.1
16	29.5	30.4	30.5	33.1
17	31.0	30.3	32.5	33.1

Raw data for **Repeated Numeral Reading** scores compared to projected curve scores:

Subject:E1:

	Time (in seconds) Raw Score	Time (in seconds) Curve Score	Errors Raw Score	Errors Curve Score
1	103	105.6	0	0
2	100	89.9	0	0
3	77	84.6	0	0
4	66	82.0	0	0
5	71	80.5	0	0
6	82	79.4	0	0
7	63	78.7	0	0
8	71	78.1	0	0
9	69	77.7	0	0
10	69	77.3	1	0
11	75	77.1	0	0
12	65	76.8	0	0
13	65	76.6	0	0
14	64	76.4	0	0
15	66	76.3	0	0
16	63	76.2	0	0
17	59	76.1	0	0

Repeated Numeral Reading Data Continued:

Subject:E2:

	Raw Score	Curve Score	Raw Score	Curve Score
1	89	88.1	0	0.2
2	77	77.5	1	0.4
3	74	73.7	0	0.5
4	72	71.8	0	0.5
5	76	70.7	0	0.5
6	70	69.9	1	0.5
7	71	69.4	1	0.6
8	77	69.0	0	0.6
9	73	68.6	0	0.5
10	63	68.4	0	0.6
11	68	68.2	0	0.6
12	71	68.0	0	0.6
13	72	67.9	1	0.6
14	71	67.7	0	0.6
15	64	67.7	1	0.6
16	66	67.6	0	0.6
17	70	67.5	0	0.6

SubjectE3:

1	122	122.6	10	9.8
2	135	132.5	4	4.9
3	134	135.9	4	3.3
4	118	137.4	4	2.5
5	116	138.4	1	2.1
6	120	139.1	3	1.7
7	116	139.6	0	1.5
8	114	139.9	2	1.3
9	110	140.2	3	1.2
10	105	140.4	0	1.1
11	104	140.6	1	1.0
12	94	140.7	2	0.9
13	102	140.9	1	0.9
14	105	141.0	1	0.8
15	111	141.1	3	0.8
16	104	141.1	1	0.7
17	106	141.2	1	0.7

Repeated Numeral Reading Data Continued:

SubjectE4:

	Raw Score	Curve Score	Raw Score	Curve Score
1	122	123.0	1	1
2	109	107.0	1	1
3	100	102.0	1	1
4	102	99.1	2	1
5	91	97.5	1	1
6	80	96.5	1	1
7	84	95.7	1	1
8	77	95.2	0	1
9	80	94.7	0	1
10	81	94.4	0	1
11	77	94.1	1	1
12	76	93.9	0	1
13	68	93.7	0	1
14	71	93.5	1	1
15	77	93.4	0	1
16	70	93.2	0	1
17	69	93.1	1	1

SubjectL1:

1	600	615.7	99	109.9
2	600	559.9	89	77.5
3	600	540.9	92	66.5
4	600	532.0	90	61.4
5	380	526.4	38	58.1
6	389	522.7	31	56.0
7	405	520.0	24	54.4
8	600	518.0	57	53.3
9	594	516.3	48	52.3
10	599	515.2	73	51.6
11	600	514.1	71	51.1
12	600	513.3	63	50.5
13	600	512.6	56	50.2
14	584	512.0	55	49.8
15	383	511.5	13	49.5
16	350	511.1	23	49.3
17	549	510.6	23	49.0

Repeated Numeral Reading Data Continued:

SubjectL2:

	Raw Score	Curve Score	Raw Score	Curve Score
1	118	116.6	2	2.3
2	114	111.7	2	2.2
3	101	110.0	1	2.2
4	107	109.2	5	2.2
5	110	108.7	5	2.2
6	114	108.4	2	2.2
7	104	108.1	2	2.2
8	104	107.9	2	2.2
9	105	107.8	1	2.2
10	119	107.7	0	2.2
11	96	107.6	2	2.2
12	111	107.5	0	2.2
13	103	107.5	0	2.2
14	105	107.4	0	2.2
15	94	107.4	1	2.2
16	83	107.3	1	2.2
17	85	107.3	2	2.2

SubjectL3:

1	162	166.0	11	13.0
2	159	154.0	8	7.0
3	148	151.0	9	5.0
4	164	149.0	9	4.0
5	140	148.0	6	4.0
6	155	147.0	1	3.0
7	150	146.0	2	3.0
8	151	146.0	0	3.0
9	149	145.0	0	3.0
10	126	145.0	1	2.0
11	139	145.0	0	2.3
12	125	145.0	2	2.2
13	127	145.0	1	2.1
14	124	145.0	0	2.1
15	126	144.0	1	2.0
16	120	144.0	0	2.0
17	125	144.0	1	2.0

Repeated Numeral Reading Data Continued:

Subject:L4:

	Raw Score	Curve Score	Raw Score	Curve Score
1	102	99.9	0	0.1
2	87	91.4	1	0.7
3	88	88.5	1	0.9
4	88	87.2	1	1.0
5	85	86.3	0	1.0
6	87	85.8	2	1.0
7	83	85.4	0	1.1
8	86	85.1	2	1.1
9	84	84.8	1	1.1
10	89	84.6	1	1.1
11	89	84.5	2	1.1
12	75	84.4	1	1.1
13	75	84.3	1	1.1
14	79	84.1	0	1.1
15	70	84.1	1	1.2
16	77	84.0	0	1.2
17	79	84.0	1	1.2

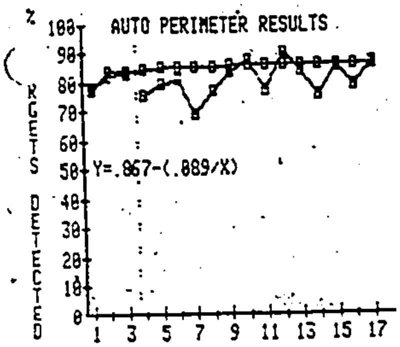
Subject:L5:

1	70	71.6	0	0.2
2	74	69.7	1	0.2
3	69	69.1	0	0.2
4	69	68.7	0	0.2
5	67	68.5	0	0.2
6	64	68.4	0	0.19
7	71	68.3	0	0.19
8	71	68.3	1	0.19
9	67	68.2	0	0.19
10	67	68.2	0	0.19
11	61	68.1	0	0.19
12	58	68.1	0	0.19
13	61	68.1	1	0.19
14	62	68.0	0	0.19
15	56	68.0	0	0.19
16	63	68.0	0	0.19
17	59	68.0	0	0.19

APPENDIX C

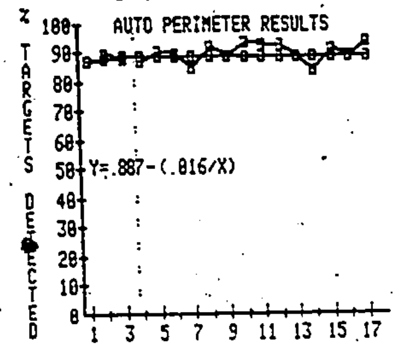
Contains graphs and figures for the repeated measures.

E1 LEFT VISUAL FIELD



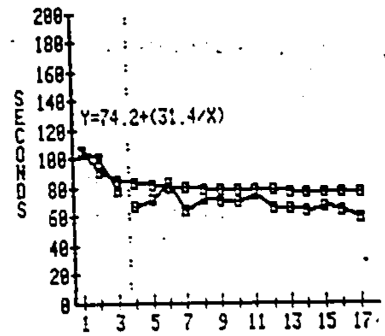
GRAPH SHOWS TREATMENT DATA IS NOT SIGNIFICANTLY ABOVE CURVE (P<.99), SUGGESTING NO TREATMENT EFFECT.

E1 RIGHT VISUAL FIELD



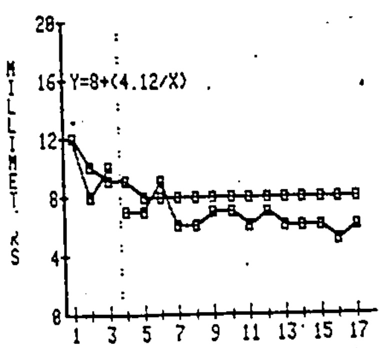
GRAPH SHOWS THAT TREATMENT DATA IS NOT SIGNIFICANTLY DIFFERENT FROM THE PROJECTED BASELINE CURVE (P<.61).

E1 REPEATED READING SPEED



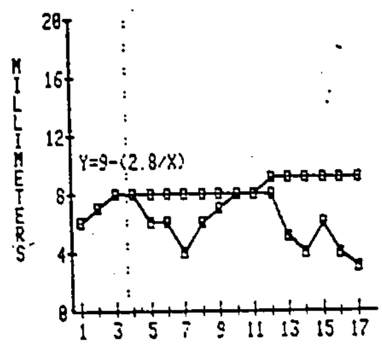
GRAPH SHOWS IMPROVED READING SPEED FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.001).

E1 LEFT HAND 2POINT THRESHOLDS



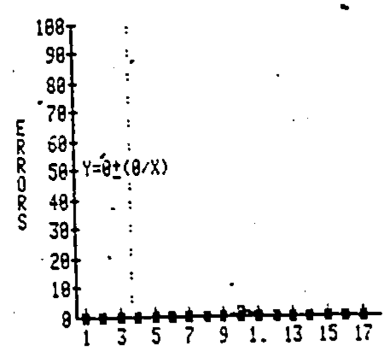
GRAPH SHOWS DATA OBTAINED DURING THE TREATMENT SESSIONS AS SIGNIFICANTLY IMPROVED (P<.001) FROM BASELINE CURVE.

E1 RIGHT HAND 2POINT THRESHOLDS



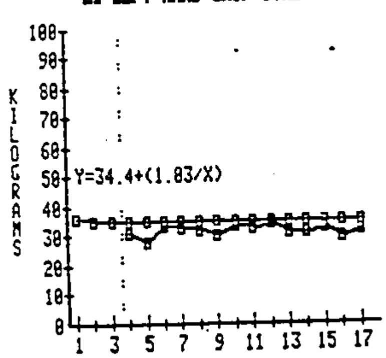
GRAPH SHOWS THRESHOLD IMPROVING DURING THE TREATMENT EXPERIMENTAL SESSIONS. THE BINOMIAL TEST YEILDS (P< .03).

E1 REPEATED READING ERRORS



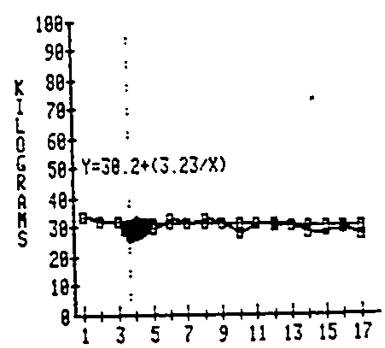
GRAPH SHOWS THAT ONLY ONE ERROR WAS MADE DURING SESSION TEN. HENCE, THERE IS NO CHANGE WITH TREATMENT (P<.999)

E1 LEFT HAND GRIP STRENGTH

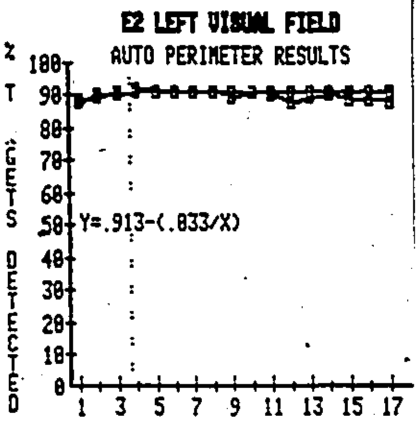


GRAPH SHOWS NO INCREASE OF DYNAMOMETER SCORE FROM PROJECTED CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.9999).

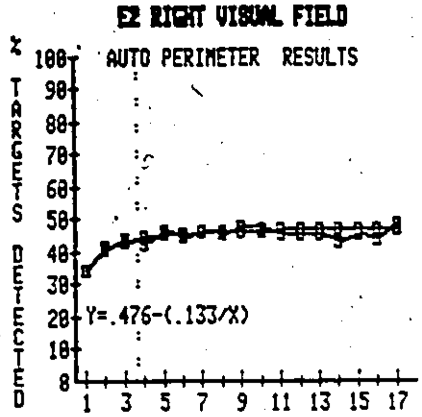
E1 RIGHT HAND GRIP STRENGTH



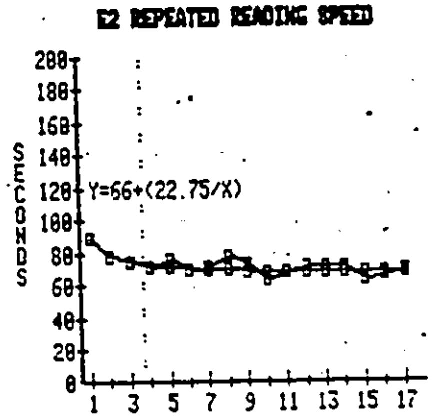
GRAPH SHOWS NO IMPROVEMENT FROM THE BASELINE PROJECTED CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.97).



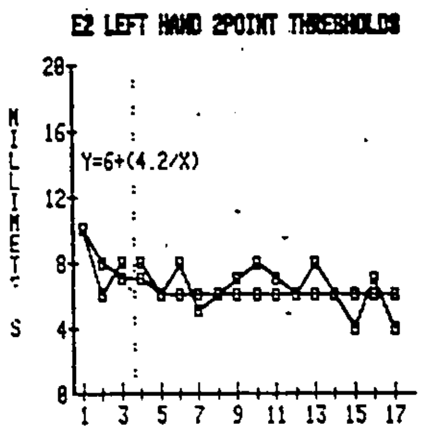
GRAPH SHOWS TREATMENT IS NOT SIGNIFICANTLY DIFFERENT FROM THE PROJECTED CURVE (P<.97).



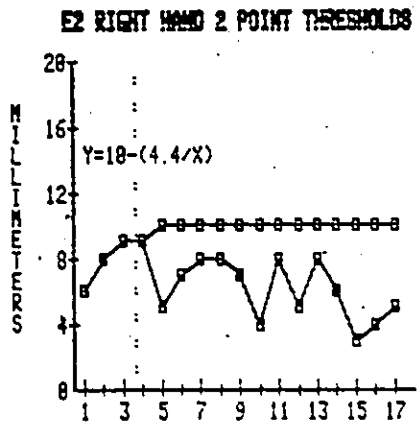
GRAPH SHOWS TREATMENT DATA IS NOT SIGNIFICANTLY DIFFERENT FROM THE BASELINE PROJECTED CURVE (P<.91).



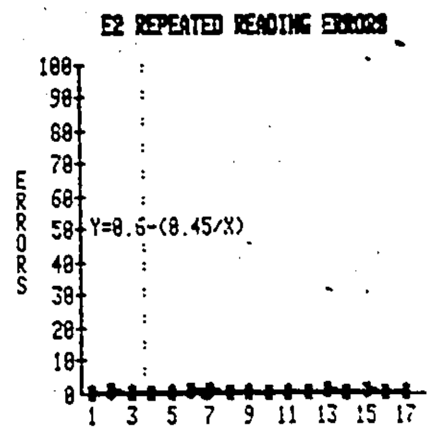
GRAPH SHOWS NO IMPROVEMENT DURING THE TREATMENT SESSIONS FROM BASELINE CUR (P<.97).



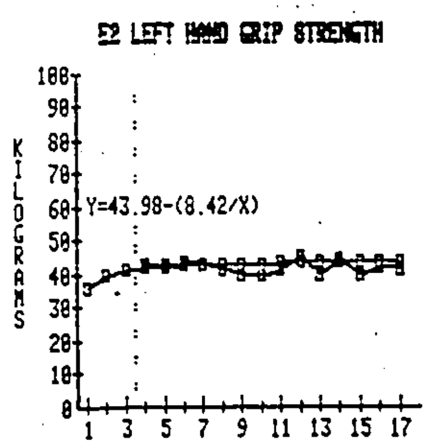
GRAPH SHOWS NO SIGNIFICANT DIFFERENCE BETWEEN THE PROJECTED BASELINE CURVE AND DATA DURING TREATMENT (P<.99).



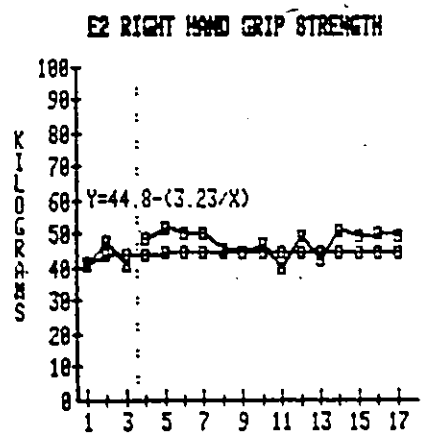
GRAPH SHOWS DATA DURING TREATMENT IS SIGNIFICANTLY IMPROVED (P<.001) OVER THE BASELINE PROJECTED CURVE.



GRAPH SHOWS LITTLE DIFFERENCE BETWEE BASELINE PROJECTED CURVE AND TREATME DATA DUE TO SO FEW ERRORS (P<.09).

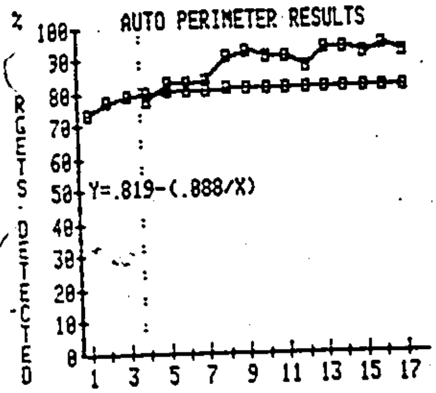


GRAPH SHOWS NO INCREASE IN DYNAMOMETER SCORE FROM BASELINE PROJETED CURVE TO TREATMENT SESSIONS DATA (P<.79).



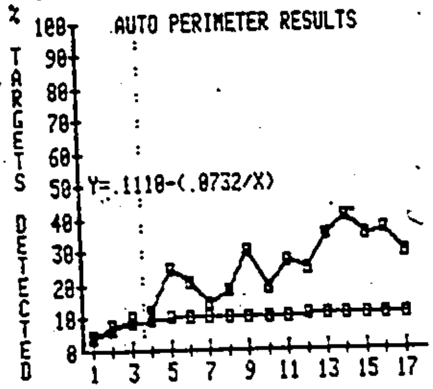
LITTLE CHANGE FROM THE PROJECTED CURVE IS SEEN VISUALLY, THOUGH THE BINOMIAL TEST SUGGESTS IMPROVEMENT (P<.83).

E3 LEFT VISUAL FIELD



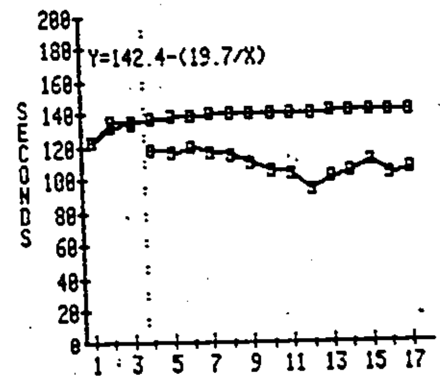
GRAPH SHOWS TREATMENT DATA POINTS SIGNIFICANTLY ABOVE PROJECTED BASELINE CURVE DATA POINTS (P<.001).

E3 RIGHT VISUAL FIELD



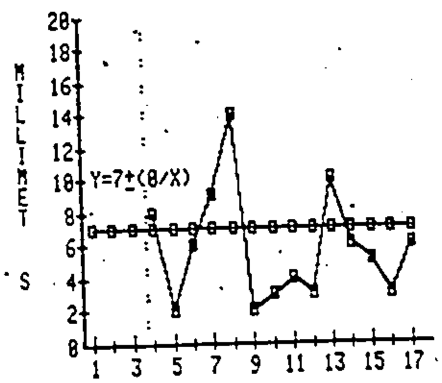
GRAPH SHOWS TREATMENT DATA SIGNIFICANTLY ABOVE (P<.0001) CURVE PROJECTED FROM THE BASELINE CONDITION.

E3 REPEATED READING SPEED



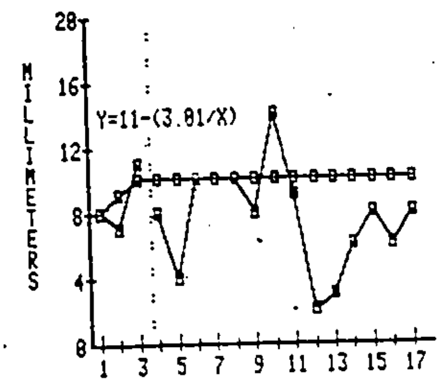
GRAPH SHOWS SIGNIFICANT IMPROVEMENT FROM PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.0001).

E3 LEFT HAND 2POINT THRESHOLDS



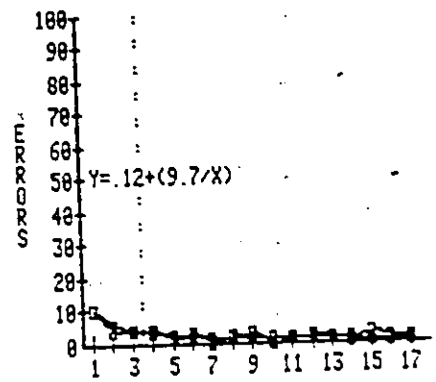
GRAPH SHOWS THAT THE BASELINE CURVE IS NOT SIGNIFICANTLY DIFFERENT (P<.09) FROM DATA OBTAINED DURING TREATMENT.

E3 RIGHT HAND 2POINT THRESHOLDS



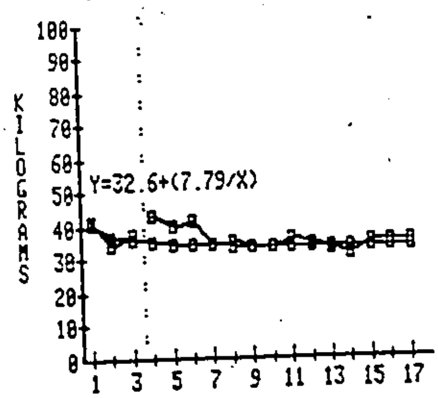
GRAPH SHOWS TREATMENT DATA APPROACHING SIGNIFICANT IMPROVEMENT FROM THE BASELINE CURVE PROJECTION (P< .09).

E3 REPEATED READING ERRORS



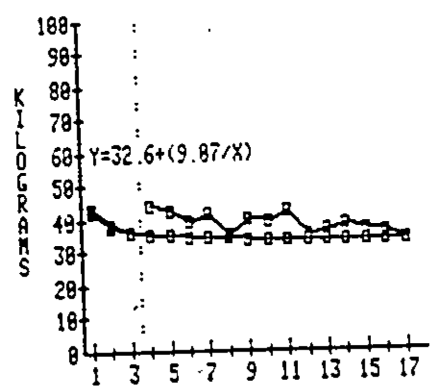
GRAPH SHOWS NO IMPROVEMENT DURING THE TREATMENT SESSIONS FROM THE PROJECTED BASELINE CURVE (P<.59).

E3 LEFT HAND GRIP STRENGTH



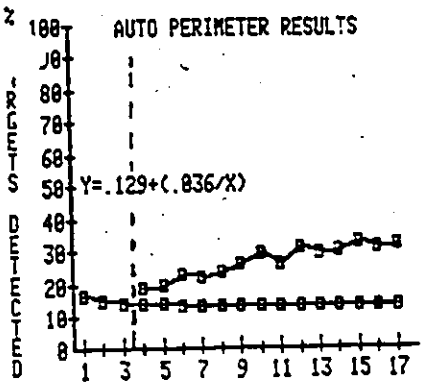
LITTLE CHANGE IS SEEN ON THE GRAPH, HOWEVER, BINOMIAL TESTING SUGGESTS AN INCREASE IN HAND STRENGTH (P<.03).

E3 RIGHT HAND GRIP STRENGTH



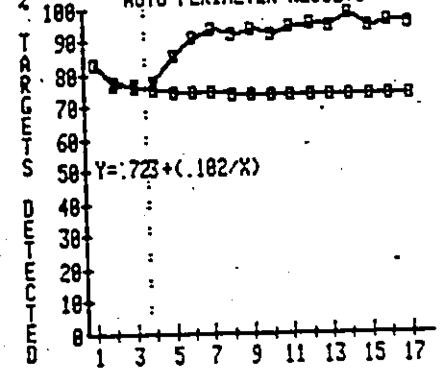
GRAPH SHOWS IMPROVEMENT IN STRENGTH FROM THE PROJECTED CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.001).

E4 LEFT VISUAL FIELD



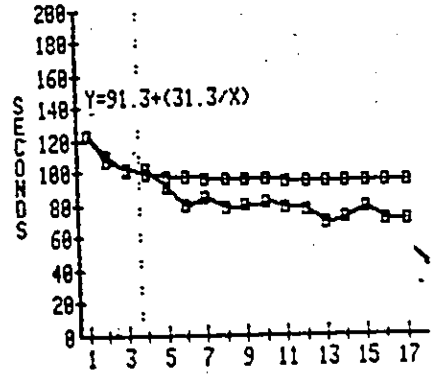
GRAPH SHOWS TREATMENT DATA POINTS SIGNIFICANTLY ABOVE PROJECTED CURVE DATA POINTS (P<.0001).

E4 RIGHT VISUAL FIELD
AUTO PERIMETER RESULTS



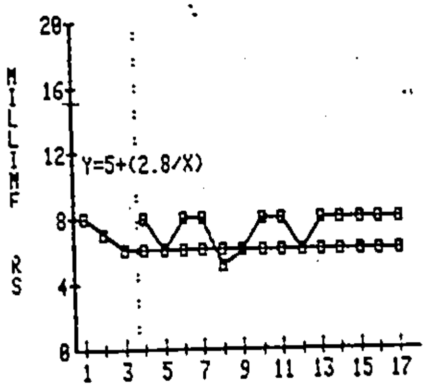
GRAPH SHOWS TREATMENT DATA SIGNIFICANTLY ABOVE (P<.0001) THE CURVE PROJECTED FROM THE BASELINE CONDITION.

E4 REPEATED READING SPEED



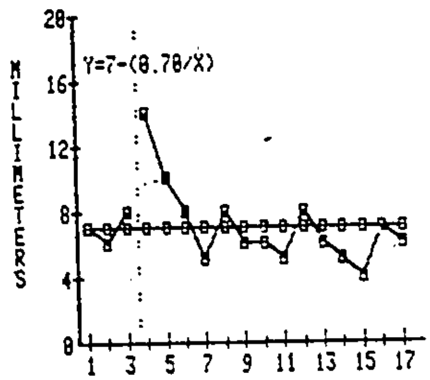
GRAPH SHOWS SIGNIFICANT IMPROVEMENT FROM THE PROJECTED CURVE THROUGH THE TREATMENT SESSIONS (P<.0001).

E4 LEFT HAND 2POINT THRESHOLDS



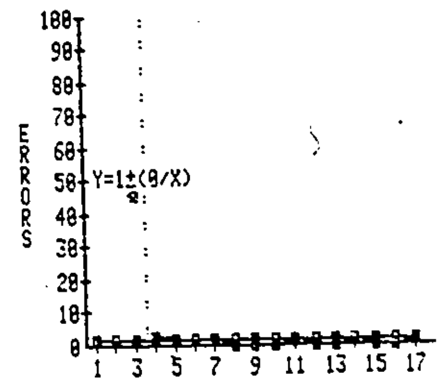
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.999).

E4 RIGHT HAND 2POINT THRESHOLDS



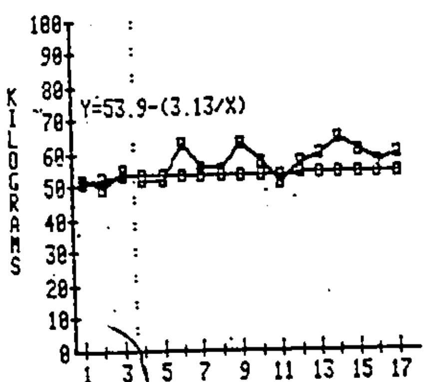
GRAPH SHOWS NO SIGNIFICANT DIFFERENCE FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS (P<.40).

E4 REPEATED READING ERRORS



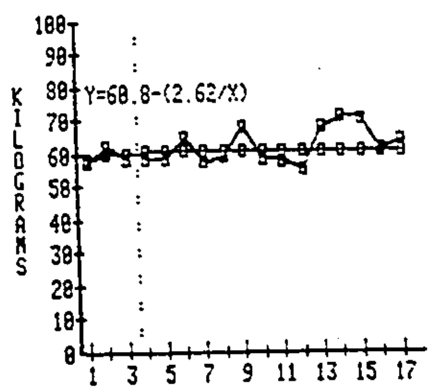
GRAPH SHOWS NO DIFFERENCE BETWEEN TH PROJECTED CURVE AND TREATMENT SESSIO (P<.61) DUE TO SO FEW ERRORS.

E4 LEFT HAND GRIP STRENGTH

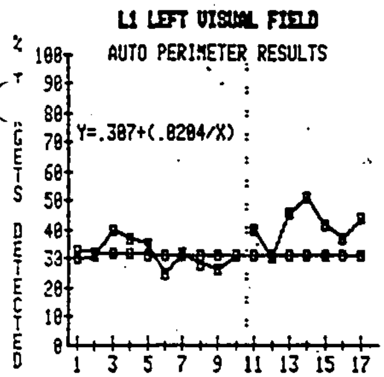


GRAPH SHOWS IMPROVEMENT FROM PROJECTED BASELINE CURVE THROUGH TREATMENT DATA ON THE BINOMIAL TEST (P<.03).

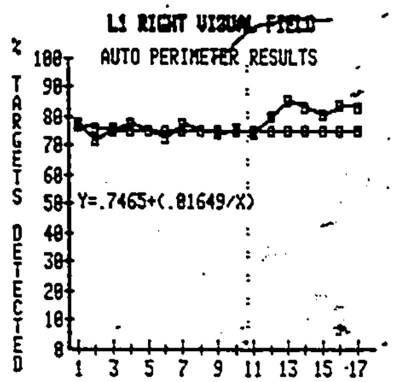
E4 RIGHT HAND GRIP STRENGTH



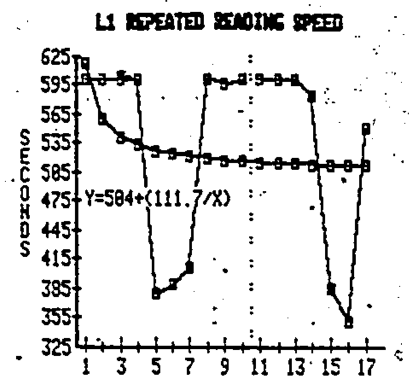
GRAPH SHOWS NO DIFFERENCE FROM THE PROJECTED BASELINE CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.61).



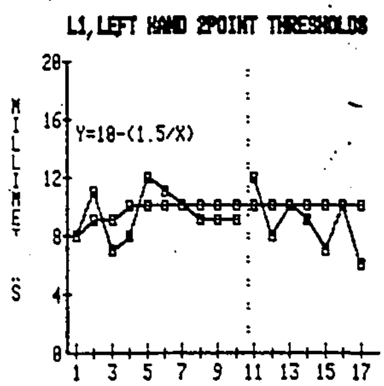
GRAPH SHOWS TREATMENT DATA ABOVE PROJECTED CURVE DATA (P<.06). TREATMENT STARTED AT SESSION 11.



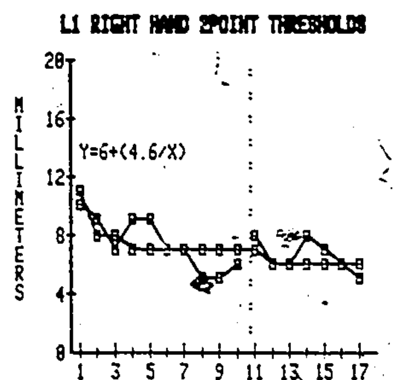
GRAPH SHOWS TREATMENT DATA ABOVE PROJECTED CURVE DATA (P<.06). TREATMENT STARTED AT SESSON 11.



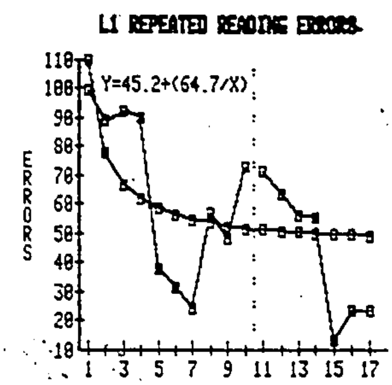
GRAPH SHOWS VARIABLE PERFORMANCE ANG THE TREATMENT SESSIONS DATA ARE NOT IMPROVED FROM BASELINE CURVE (P<.94).



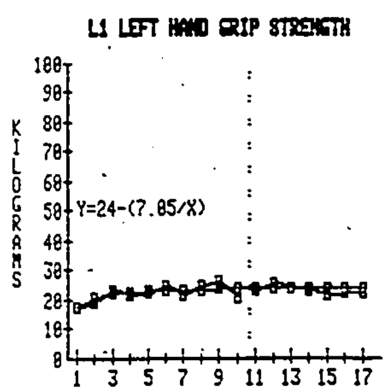
GRAPH SHOWS NO SIGNIFICANT DIFFERENCE FROM BASELINE PROJECTED CURVE THROUGH TREATMET SESSIONS DATA (P<.50).



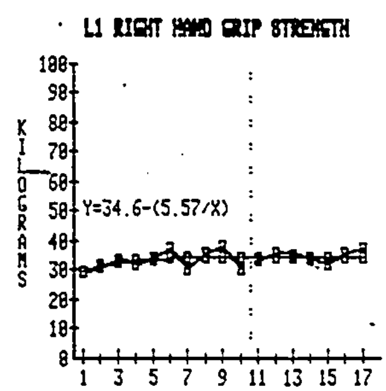
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT DATA SESSIONS (P<.99).



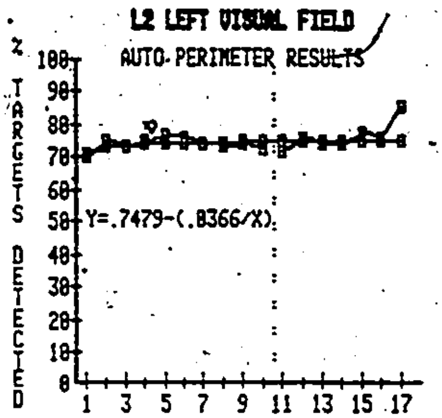
GRAPH SHOWS NO SIGNIFICANT IMPROVEMEN FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.77).



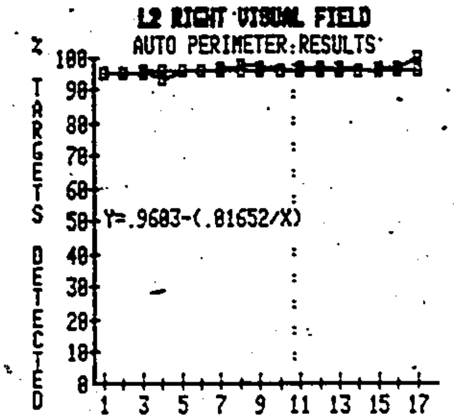
RAPH SHOWS NO IMPROVEMENT FROM THE PROJECTED BASELINE CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.94).



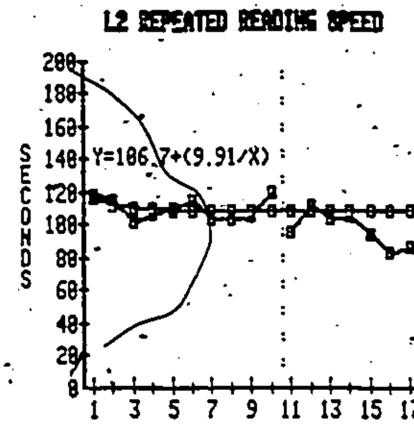
GRAPH SHOWS NO DIFFERENCE FROM THE PROJECTED BASELINE CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.50).



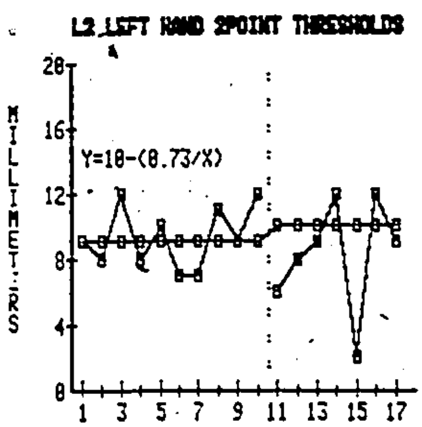
GRAPH SHOWS TREATMENT DATA IS NOT DIFFERENT FROM CURVE (P<.50). TREATMENT STARTED AT SESSION 11.



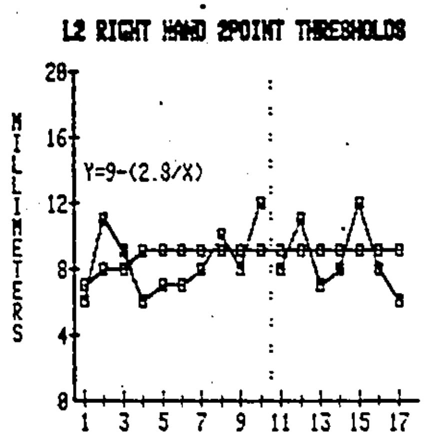
THOUGH VISUAL INSPECTION SHOWS NO EFFECT, THE BINOMIAL TESTS (P<.06) SUGGESTS THAT TREATMENT DATA APPROACHES SIGNIFICANCE.



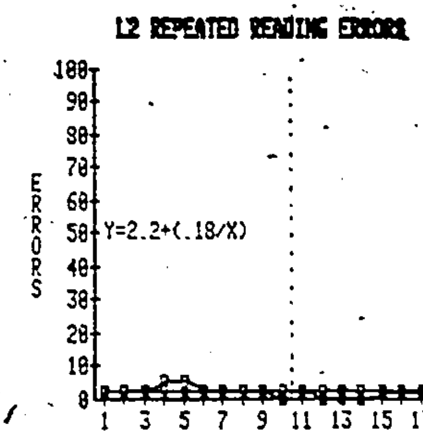
GRAPH SHOWS IMPROVED SPEED DURING TREATMENT SESSIONS COMPARED TO BASELINE PROJECTED CURVE (P<.01).



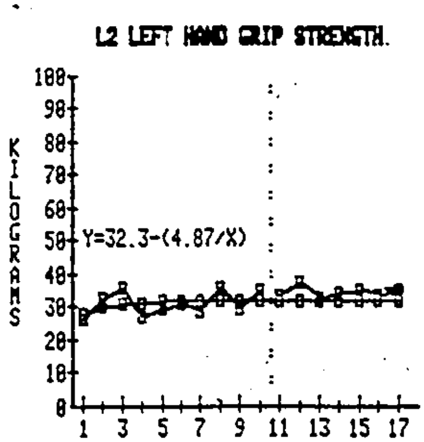
GRAPH SHOWS NO SIGNIFICANT DIFFERENCE FROM BASELINE PROJECTED CURVE THROUGH THE TREATMENT SESSIONS DATA (P<.23).



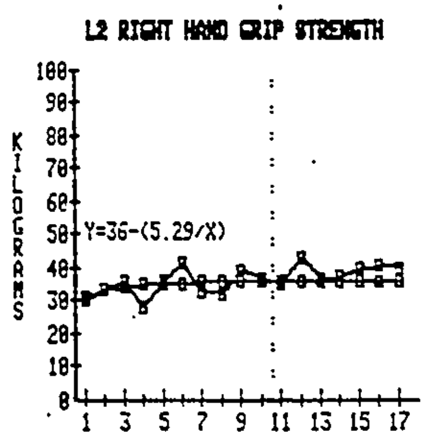
GRAPH SHOWS NO SIGNIFICANT DIFFERENCE FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.23).



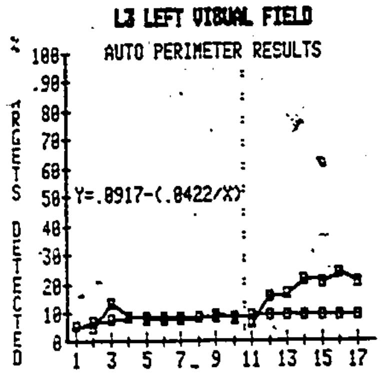
LITTLE CHANGE IS APPARENT VISUALLY HOWEVER, THE BINOMIAL TEST SUGGESTS FEWER ERRORS DURING TREATMENT (P<.



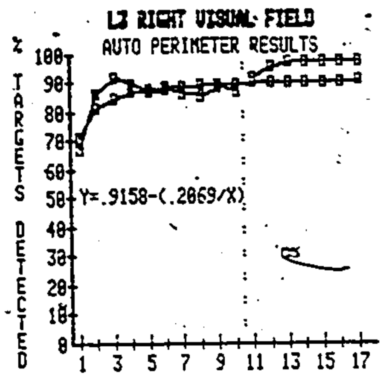
GRAPH SHOWS IMPROVEMENT FROM THE PROJECTED BASELINE CURVE THROUGH TREATMENT SESSIONS DATA (P<.01).



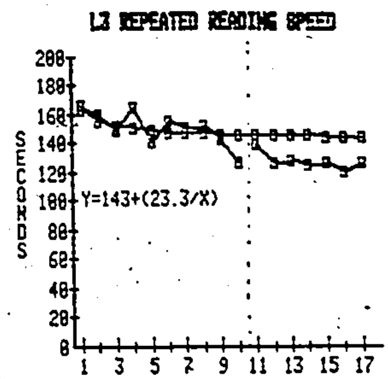
DYNAMOMETER SCORES APPROACH BEING SIGNIFICANTLY ABOVE THE PROJECTED CURVE ON BINOMIAL TESTING (P<.06).



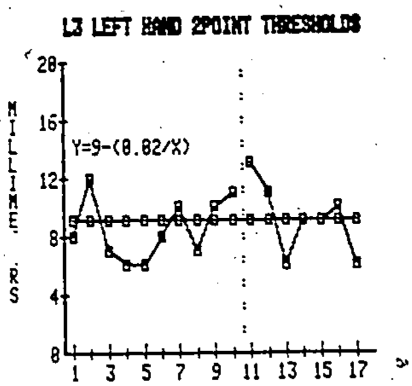
GRAPH SHOWS TREATMENT DATA POINTS ABOVE PROJECTED CURVE (P<.06). TREATMENT BEGAN AT SESSION 11.



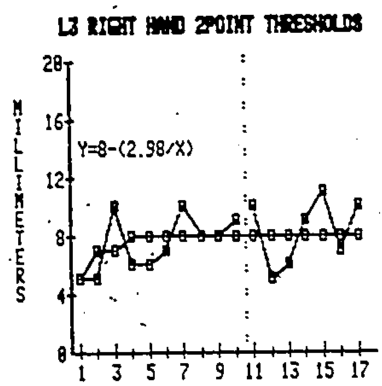
GRAPH SHOWS TREATMENT DATA POINTS SIGNIFICANTLY (P<.01) ABOVE PROJECTED CURVE DATA POINTS.



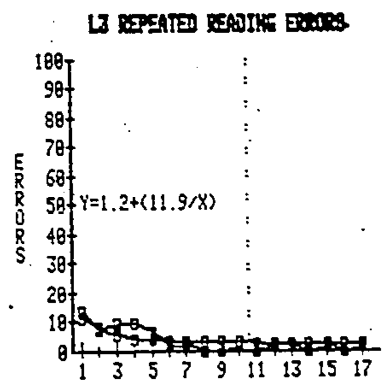
GRAPH SHOWS IMPROVED SPEEDS DURING TREATMENT SESSIONS COMPARED TO THE BASELINE PROJECTED CURVE (P<.01).



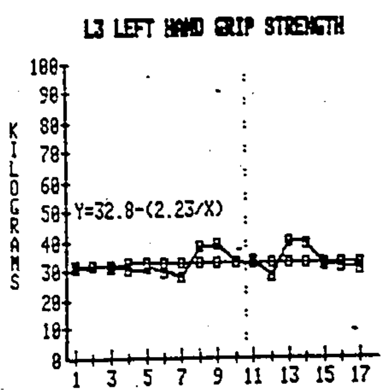
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.94).



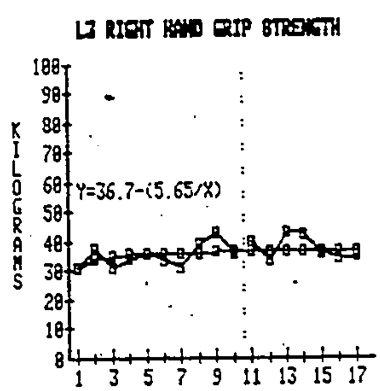
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.77).



GRAPH SHOWS A VISUAL TREND TOWARDS FEWER ERRORS DURING TREATMENT SESSIONS AND BINOMIAL TESTING CONCURS (P<.01)

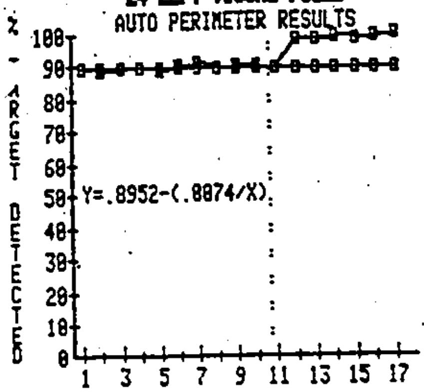


GRAPH SHOWS NO DIFFERENCE BETWEEN THE BASELINE PROJECTED CURVE AND THE TREATMENT DATA (P<.77).



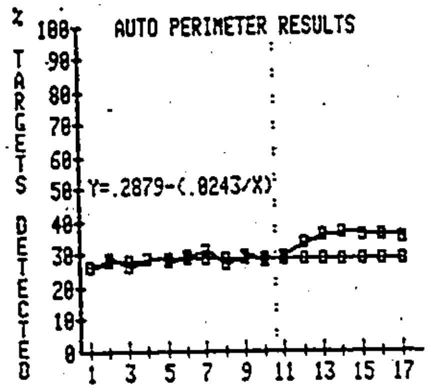
GRAPH SHOWS NO DIFFERENCE BETWEEN THE BASELINE PROJECTED CURVE AND THE TREATMENT SESSIONS DATA (P<.50).

L4 LEFT VISUAL FIELD



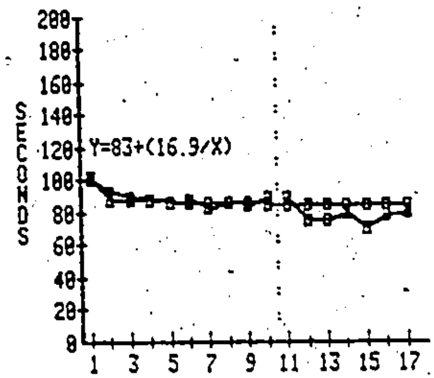
GRAPH SHOWS TREATMENT ABOVE THE PROJECTED CURVE (P.<06). TREATMENT BEGAN WITH SESSION 11.

L4 RIGHT VISUAL FIELD



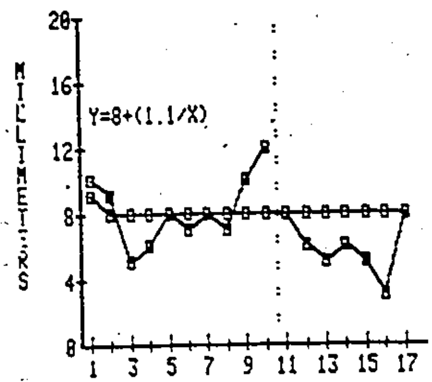
GRAPH SHOWS TREATMENT SIGNIFICANTLY ABOVE PROJECTED CURVE DATA POINTS (P<.01).TREATMENT BEGAN AT 11.

L4 REPEATED READING SPEED



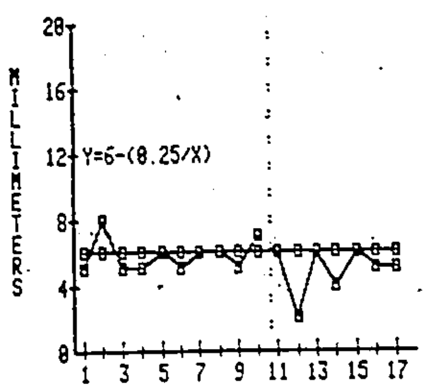
GRAPH SHOWS TREATMENT DATA APPROCHES SIGNIFICANT IMPOVEMENT WITH BINOMIAL TESTING (P<.06).

L4 LEFT HAND 2POINT THRESHOLDS



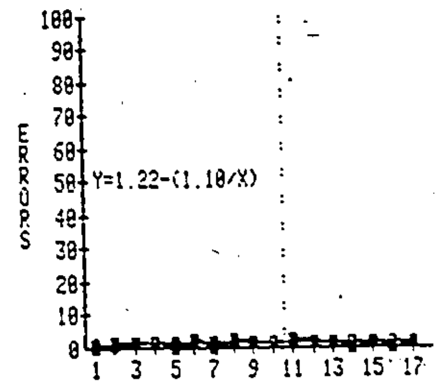
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.23).

L4 RIGHT HAND 2POINT THRESHOLDS



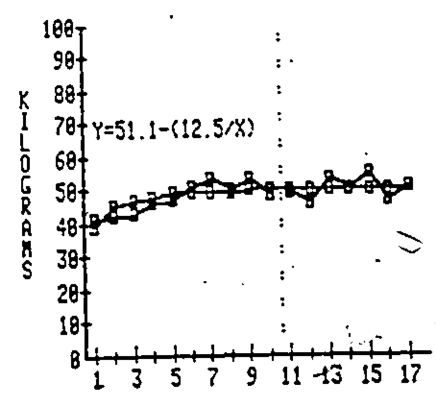
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.50).

L4 REPEATED READING ERRORS



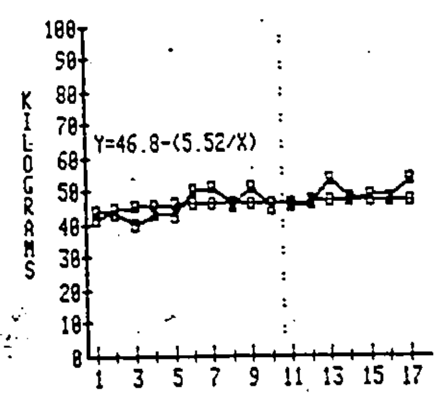
GRAPH SHOWS TOO FEW ERRORS TO INSPEC RELATIVE TREATMENT TREND.BINOMIAL TE (P<.06) SHOWS TREND APPROACHES IMPROVEME

L4 LEFT HAND GRIP STRENGTH



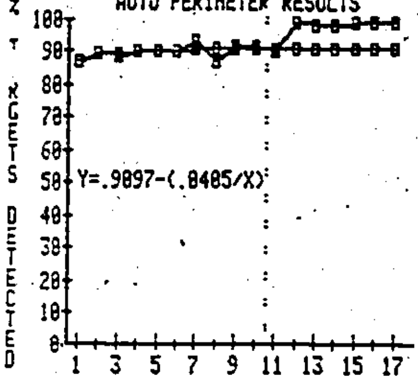
GRAPH SHOWS NO DIFFERENCE BETWEEN BASELINE PROJECTED CURVE AND THE DATA FROM THE TREATMENT SESSIONS (P<.50).

L4 RIGHT HAND GRIP STRENGTH



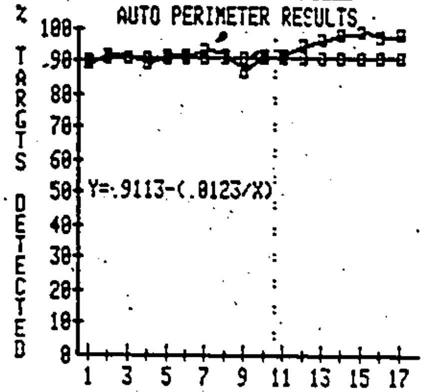
GRAPH SHOWS NO DIFFERENCE BETWEEN THE BASELINE PROJECTED CURVE AND THE DATA FROM THE TREATMENT SESSONS (P<.23).

L5 LEFT VISUAL FIELD
AUTO PERIMETER RESULTS



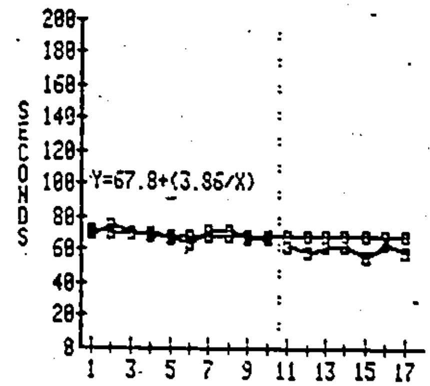
GRAPH SHOWS TREATMENT ABOVE THE PROJECTED CURVE (P<.06). TREATMENT BEGAN ON SESSION 11.

L5 RIGHT VISUAL FIELD
AUTO PERIMETER RESULTS



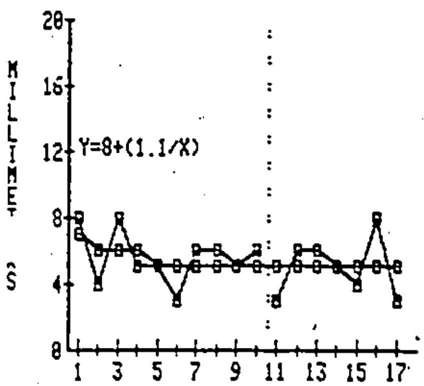
GRAPH SHOWS TREATMENT DATA POINTS ABOVE PROJECTED CURVE POINTS (P<.06). TREATMENT BEGAN AT SESSION 11.

L5 REPEATED READING SPEED



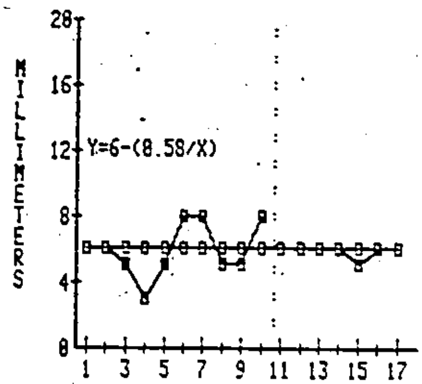
GRAPH SHOWS IMPROVED SPEED DURING TREATMENT DATA WITH BINOMIAL TEST (P<.01).

L5 LEFT HAND 2POINT THRESHOLDS



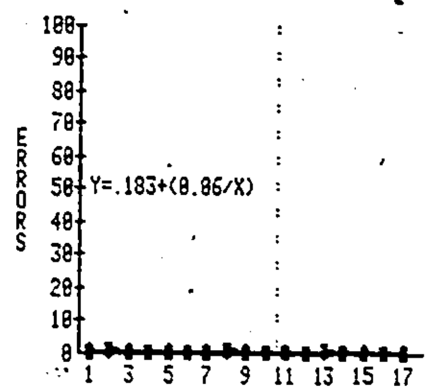
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.77).

L5 RIGHT HAND 2POINT THRESHOLDS



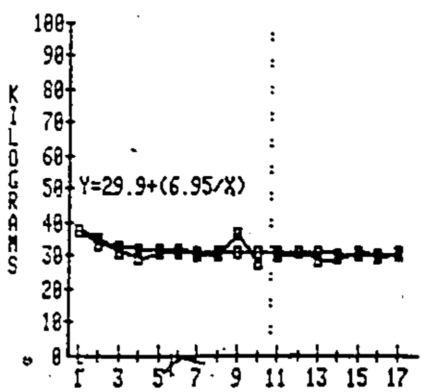
GRAPH SHOWS NO SIGNIFICANT IMPROVEMENT FROM BASELINE PROJECTED CURVE THROUGH TREATMENT SESSIONS DATA (P<.99).

L5 REPEATED READING ERRORS



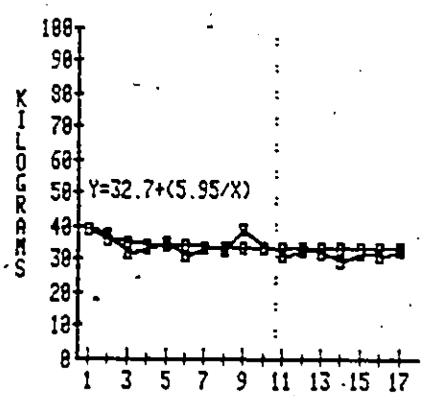
GRAPH SHOWS TOO FEW ERRORS TO INSPECT RELATIVE TREATMENT TREND.BINOMIAL TES (P<.06) APPROACHES SIGNIFICANCE.

L5 LEFT HAND GRIP STRENGTH



RAPH SHOWS NO IMPROVEMENT DURING THE THE TREATMENT SESSIONS (P<.94).

L5 RIGHT HAND GRIP STRENGTH



GRAPH SHOWS NO IMPROVEMENT DURING THE TREATMENT SESSIONS (P<.999).

APPENDIX D

Contains raw scores for measures collected on the three "Observation" days.

CHAPMAN-COOK SPEED of READING TEST

Subject		Score (30 possible)	Time (in seconds)
E1	01	29	227
	02	30	256
	03	30	184
E2	01	30	297
	02	29	290
	03	30	230
E3	01	30	542
	02	28	555
	03	30	515
E4	01	29	430
	02	29	570
	03	30	319
L1	01	0	D/C at 10 min.
	02	0	D/C at 10 min.
	03	0	D/C at 10 min.
L2	01	29	350
	02	30	635
	03	30	492
L3	01	26	1,976
	02	24	2,239
	03	24	1,762
L4	01	30	455
	02	29	463
	03	30	354
L5	01	30	345
	02	30	383
	03	30	325

Table above indicates raw data for Chapman-Cook Speed of Reading Test.

"01" = observation day 1.

"02" = observation day 2.

"03" = observation day 3.

W R A T

Subject		Score (89 possible)	Time (in seconds)
E1	01	73	100
	02	76	95
	03	77	72
E2	01	75	55
	02	73	87
	03	75	98
E3	01	52	176
	02	52	148
	03	52	132
E4	01	69	171
	02	67	146
	03	66	120
L1	01	0	D/C at 10 min.
	02	0	D/C at 10 min.
	03	9	D/C at 10 min.
L2	01	76	275
	02	67	185
	03	77	170
L3	01	11	268
	02	6	330
	03	10	182
L4	01	33	138
	02	36	135
	03	41	186
L5	01	77	78
	02	76	70
	03	79	70

Table above indicates raw data for WRAT.

"01" = observation day 1.

"02" = observation day 2.

"03" = observation day 3.

GATES-MacGINITIE READING TEST

Subject		Score (43 possible)	Time (in seconds)
E1	01	39	863
	02	40	1,030
	03	38	885
E2	01	39	929
	02	43	1,154
	03	41	969
E3	01	31	2,085
	02	24	2,181
	03	34	2,162
E4	01	40	1,222
	02	32	967
	03	41	1,032
L1	01	0	D/C at 1 hour
	02	0	D/C at 1 hour
	03	2	D/C at 1 hour
L2	01	39	1,493
	02	40	2,289
	03	40	1,982
L3	01	18	4,545
	02	19	4,117
	03	21	3,490
L4	01	33	1,680
	02	32	1,616
	03	31	1,755
L5	01	43	1,138
	02	43	1,100
	03	43	909

Table above indicates raw data for Gates-MacGinitie Reading Tests.

"01" = observation day 1.

"02" = observation day 2.

"03" = observation day 3.

"H" CANCELLATION

Subject		Score (105 possible)	Time (in seconds)
E1	O1	103	93
	O2	105	100
	O3	105	29
E2	O1	104	110
	O2	99	115
	O3	104	102
E3	O1	105	185
	O2	105	175
	O3	105	173
E4	O1	103	120
	O2	103	122
	O3	105	110
L1	O1	38	373
	O2	69	423
	O3	92	496
L2	O1	95	134
	O2	97	145
	O3	98	140
L3	O1	104	163
	O2	105	170
	O3	105	121
L4	O1	103	95
	O2	105	94
	O3	105	105
L5	O1	105	108
	O2	105	94
	O3	105	101

Tabled above are the raw scores for the Cancellation task. The "O1" indicates "Observation day" one. "O2" indicates "Observation day" two. "O3" indicates "Observation day" three.

GOLDMANN PERIMETRY

Subject		Left Eye (mm^2)		Right Eye (mm^2)	
		LVF	RVF	LVF	RVF
E1	O1	7,875	4,738	5,131	9,913
	O2	8,431	5,587	5,583	9,272
	O3	7,223	6,131	4,904	8,614
E2	O1	8,496	2,399	5,484	3,835
	O2	9,471	3,700	6,092	6,171
	O3	7,622	2,791	5,363	4,143
E3	O1	8,175	0	3,253	64
	O2	7,256	0	2,579	0
	O3	6,475	0	3,198	154
E4	O1	353	5,395	451	8,106
	O2	1,487	5,981	935	9,222
	O3	1,408	5,492	1,184	9,539
L1	O1	*	*	1,622	7,857
	O2	*	*	2,774	8,928
	O3	*	*	2,896	7,953
L2	O1	6,173	5,222	2,994	10,588
	O2	5,339	5,910	3,288	9,226
	O3	5,104	5,743	3,519	10,486
L3	O1	78	3,910	0	8,432
	O2	20	3,529	262	9,402
	O3	0	3,469	103	8,348
L4	O1	8,975	1,780	5,792	2,803
	O2	9,059	2,521	5,624	3,493
	O3	8,723	2,185	6,280	3,541
L5	O1	9,619	6,053	7,142	10,468
	O2	10,131	6,511	7,084	10,440
	O3	8,695	5,843	6,616	10,296

Table above indicates raw data of visual field measurements, in square millimeters, on the Goldmann Perimeter.
"O1" = observation day 1.
"O2" = observation day 2.
"O3" = observation day 3.
"*" = test not administered.

BOX SEARCH

Subject		Score (100 possible)	Time (in seconds)
E1	O1	73	226
	O2	95	255
	O3	96	237
E2	O1	100	172
	O2	99	170
	O3	100	136
E3	O1	98	235
	O2	98	231
	O3	100	216
E4	O1	97	225
	O2	100	241
	O3	97	191
L1	O1	86	740
	O2	95	901
	O3	94	671
L2	O1	96	304
	O2	89	291
	O3	99	264
L3	O1	99	280
	O2	99	278
	O3	99	251
L4	O1	98	204
	O2	100	188
	O3	99	162
L5	O1	99	141
	O2	100	154
	O3	99	132

Tabled above are the raw scores for the Box Search task.
"O1" = observation day 1.
"O2" = observation day 2.
"O3" = observation day 3.

LINE BISECTION

Subject		Score (in mm) (True Half = 1,568 mm)	Time (in seconds)
E1	O1	1,551	42
	O2	1,530	41
	O3	1,521	39
E2	O1	1,690	31
	O2	1,702	33
	O3	1,670	26
E3	O1	1,713	62
	O2	1,584	62
	O3	1,639	61
E4	O1	1,462	195
	O2	1,428	260
	O3	1,455	105
L1	O1	1,435	230
	O2	1,542	273
	O3	1,416	170
L2	O1	1,704	110
	O2	1,628	175
	O3	1,635	130
L3	O1	1,684	97
	O2	1,672	105
	O3	1,669	95
L4	O1	1,577	60
	O2	1,582	58
	O3	1,547	46
L5	O1	1,612	34
	O2	1,604	30
	O3	1,640	35

Table above indicates raw data for Line Bisection task.
Score refers to sum of measured left half (in millimeters) of 20 lines.
True measured left half of 20 lines = 1,568 millimeters.
Time indicates amount of time, in seconds, taken to complete task.
"O1" = observation day 1.
"O2" = observation day 2.
"O3" = observation day 3.

VISUAL SEARCH

Subject		Left Visual Field Score	Left Visual Field Time	Right Visual Field Score	Right Visual Field Time
E1	O1	10	53	10	43
	O2	12	33	8	45
	O3	11	35	9	59
E2	O1	9	104	11	43
	O2	6	52	14	54
	O3	6	77	14	44
E3	O1	14	147	6	45
	O2	11	125	9	59
	O3	13	43	7	62
E4	O1	8	60	12	110
	O2	10	59	10	40
	O3	10	42	10	35
L1	O1	4	969	9	1,463
	O2	5	805	7	1,278
	O3	7	882	8	593
L2	O1	9	96	11	163
	O2	8	61	12	73
	O3	8	105	12	68
L3	O1	8	87	12	95
	O2	11	88	9	76
	O3	10	71	10	88
L4	O1	12	108	8	87
	O2	10	103	10	50
	O3	12	28	9	151
L5	O1	9	69	11	32
	O2	11	50	9	53
	O3	8	74	12	109

Table above indicates raw data for Visual Search task.
Score indicates number of targets detected in each visual field.
Time refers to total time taken, in seconds, to detect targets.
"O1" = observation day 1.
"O2" = observation day 2.
"O3" = observation day 3.

VISUAL SCAN

Subject		Horizontal Score	Horizontal Time	Vertical Score	Vertical Time
E1	O1	9	5.55	10	5.2
	O2	10	5.6	9	5.7
	O3	10	6.6	10	6.0
E2	O1	10	4.8	8	4.5
	O2	10	4.9	9	3.9
	O3	10	4.4	10	4.6
E3	O1	9	4.98	6	5.5
	O2	9	5.9	10	5.7
	O3	9	4.9	9	5.18
E4	O1	10	7.0	9	7.35
	O2	10	6.1	10	6.7
	O3	10	6.7	10	7.5
L1	O1	1	11.0	1	28.0
	O2	3	14.0	0	*
	O3	8	22.5	5	28.38
L2	O1	9	8.08	10	9.4
	O2	10	8.6	10	7.4
	O3	10	8.2	10	7.1
L3	O1	9	9.1	10	8.9
	O2	10	11.1	9	9.18
	O3	9	7.23	10	6.6
L4	O1	9	7.1	10	7.1
	O2	10	5.6	9	3.43
	O3	10	4.6	10	5.9
L5	O1	9	6.15	8	5.0
	O2	10	6.3	10	5.2
	O3	10	5.0	10	3.5

Table above indicates raw data for Visual Scanning task.
Maximum score possible = 10.
Time = average time (in seconds) for correct responses.
"*" indicates no average time available, due to zero correct responses.
"O1" = observation day 1.
"O2" = observation day 2.
"O3" = observation day 3.

APPENDIX E

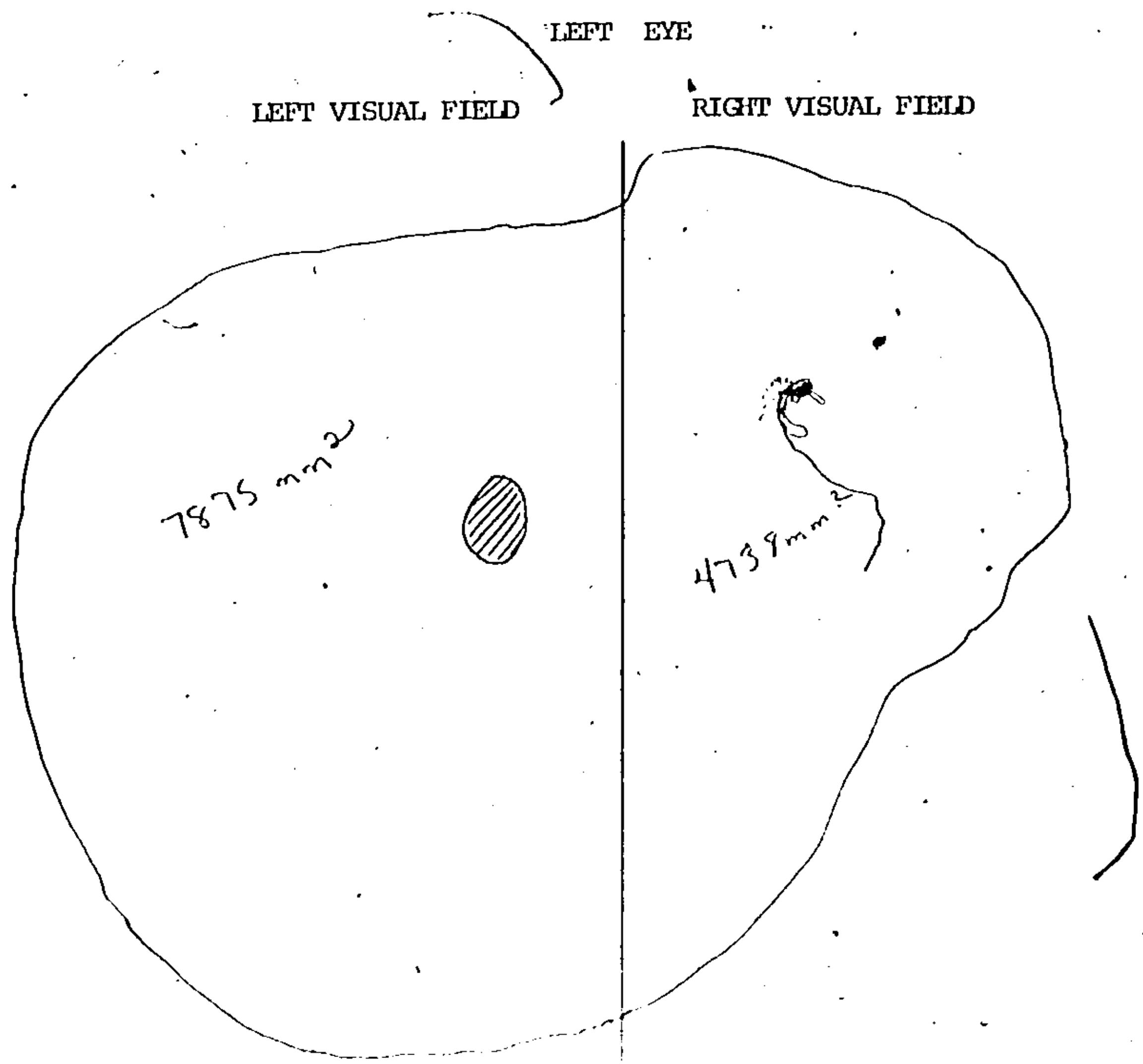
Contains Table of luminance Units and graphs for O1 and O2 areas of functioning visual fields measured by the IV isopter on the Goldmann Perimeter.

Table shows luminance comparisons.

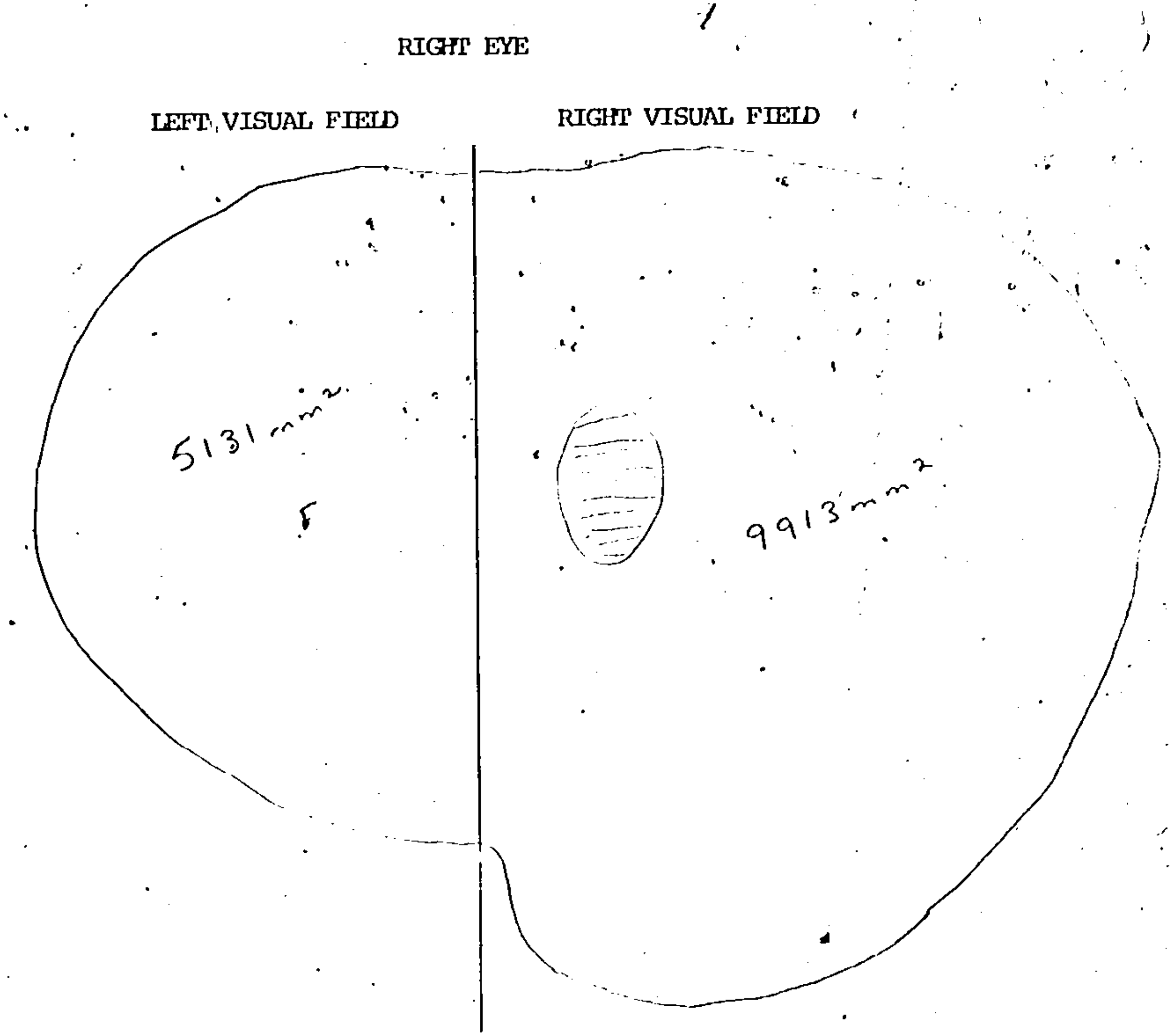
Approx. Gold-mann Equiv.	Apo-* stilbs (asb)	Log Units
I 1a	0.13	4.9
1b	0.16	4.8
1c	0.2	4.7
1d	0.25	4.6
1e	0.32	4.5
2a	0.4	4.4
2b	0.5	4.3
2c	0.63	4.2
2d	0.8	4.1
2e	1.0	4.0
3a	1.3	3.9
3b	1.6	3.8
3c	2	3.7
3d	2.5	3.6
3e	3.2	3.5
4a	4.0	3.4
4b	5	3.3
4c	6.3	3.2
4d	8	3.1
4e	10	3.0
1a	13	2.9
1b	16	2.8
1c	20	2.7
1d	25	2.6
1e	32	2.5
2a	40	2.4
2b	50	2.3
2c	63	2.2
2d	80	2.1
2e	100	2.0
3a	130	1.9
3b	160	1.8
3c	200	1.7
3d	250	1.6
3e	320	1.5
4a	400	1.4
4b	500	1.3
4c	630	1.2
4d	800	1.1
4e	1K	1.0
II 4a	1.25K	.9
4b	1.6K	.8
4c	2K	.7
4d	2.5K	.6
4e	3.2K	.5
III 4a	4K	.4
4b	5K	.3
4c	6.3K	.2
4d	8K	.1
4e	10K	0

* Apostilb: A unit of luminance equal to 1/10 millilambert.

E1 O1 K.P. Left Eye

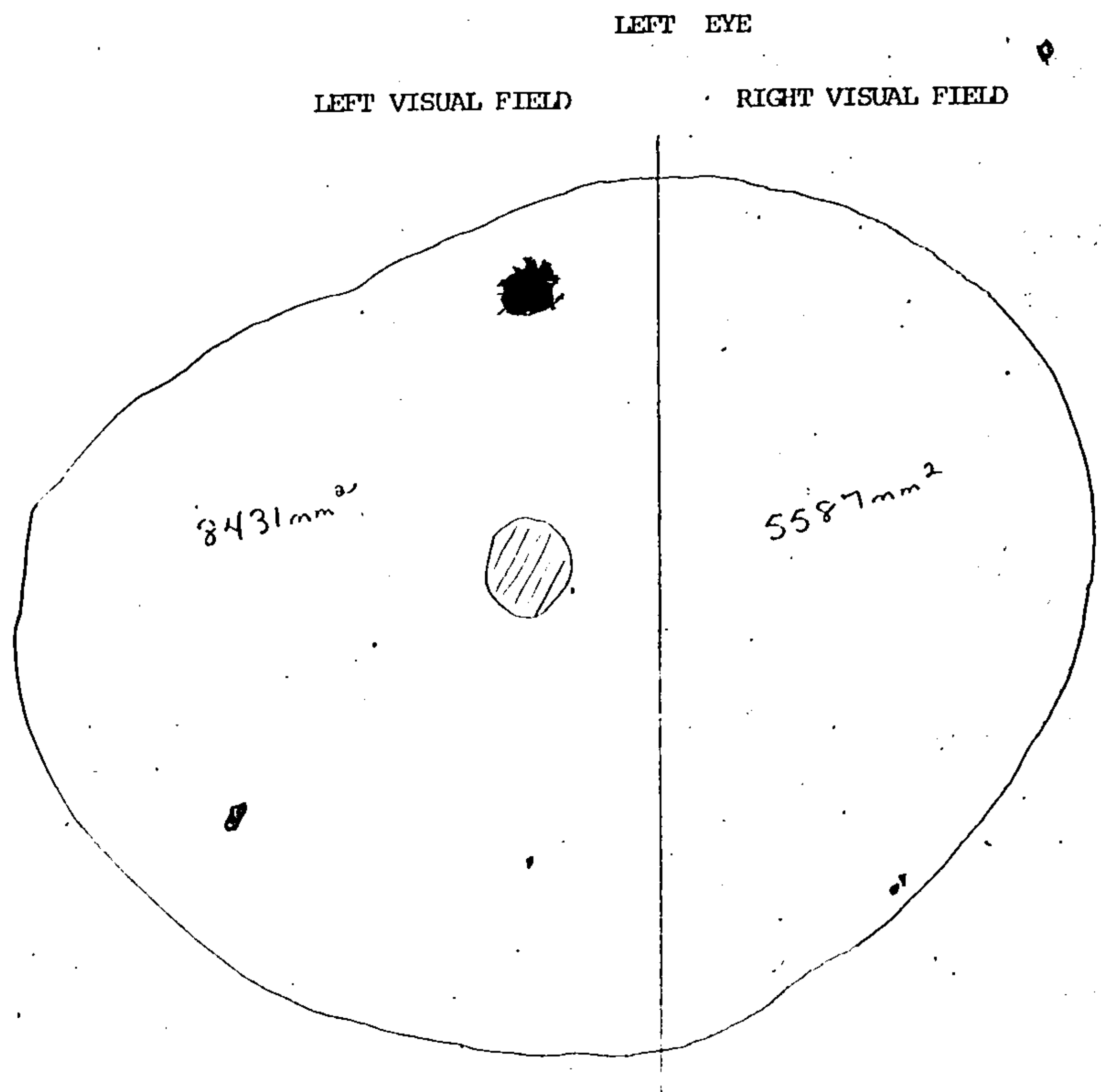


Subject E1. Area of functioning visual field (measured in square millimeters) on "O1".



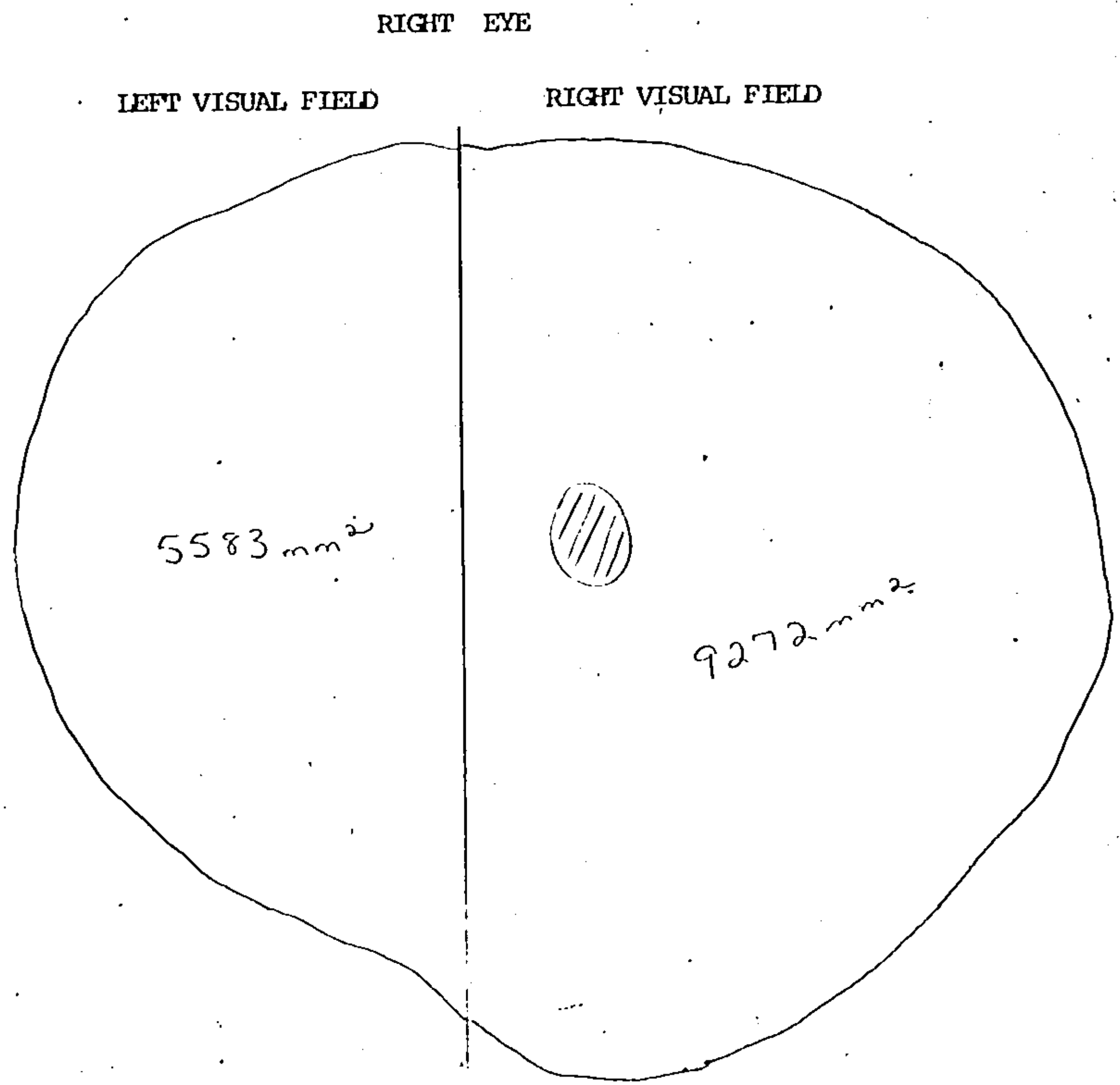
Subject E1. Area of functioning visual field (measured in square millimeters) on "O1".

O2
K. P.
L. Eye

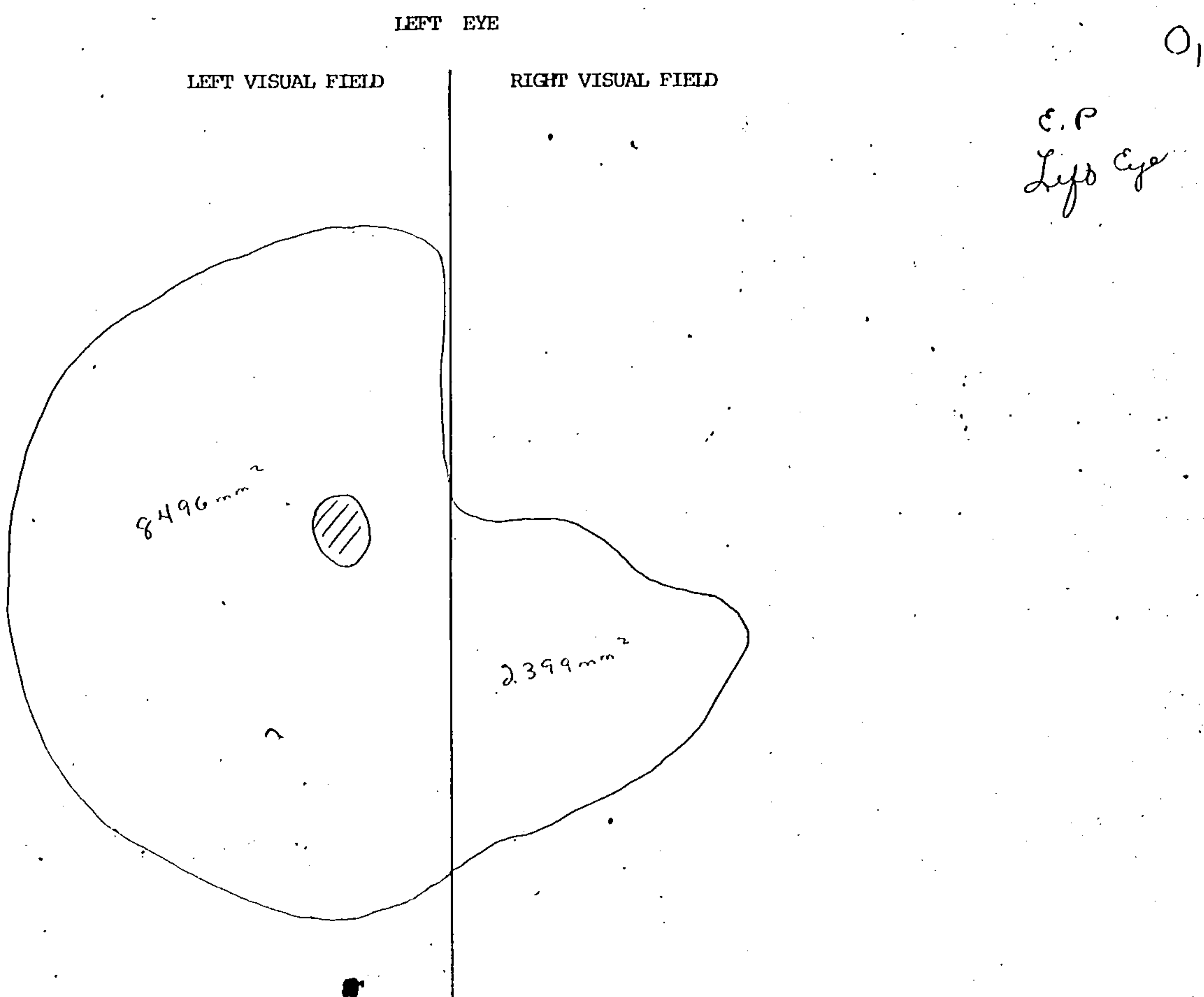


Subject E1. Area of functioning visual field (measured in square millimeters) on "O2".

O2
R.P.
Bo. Eye
1



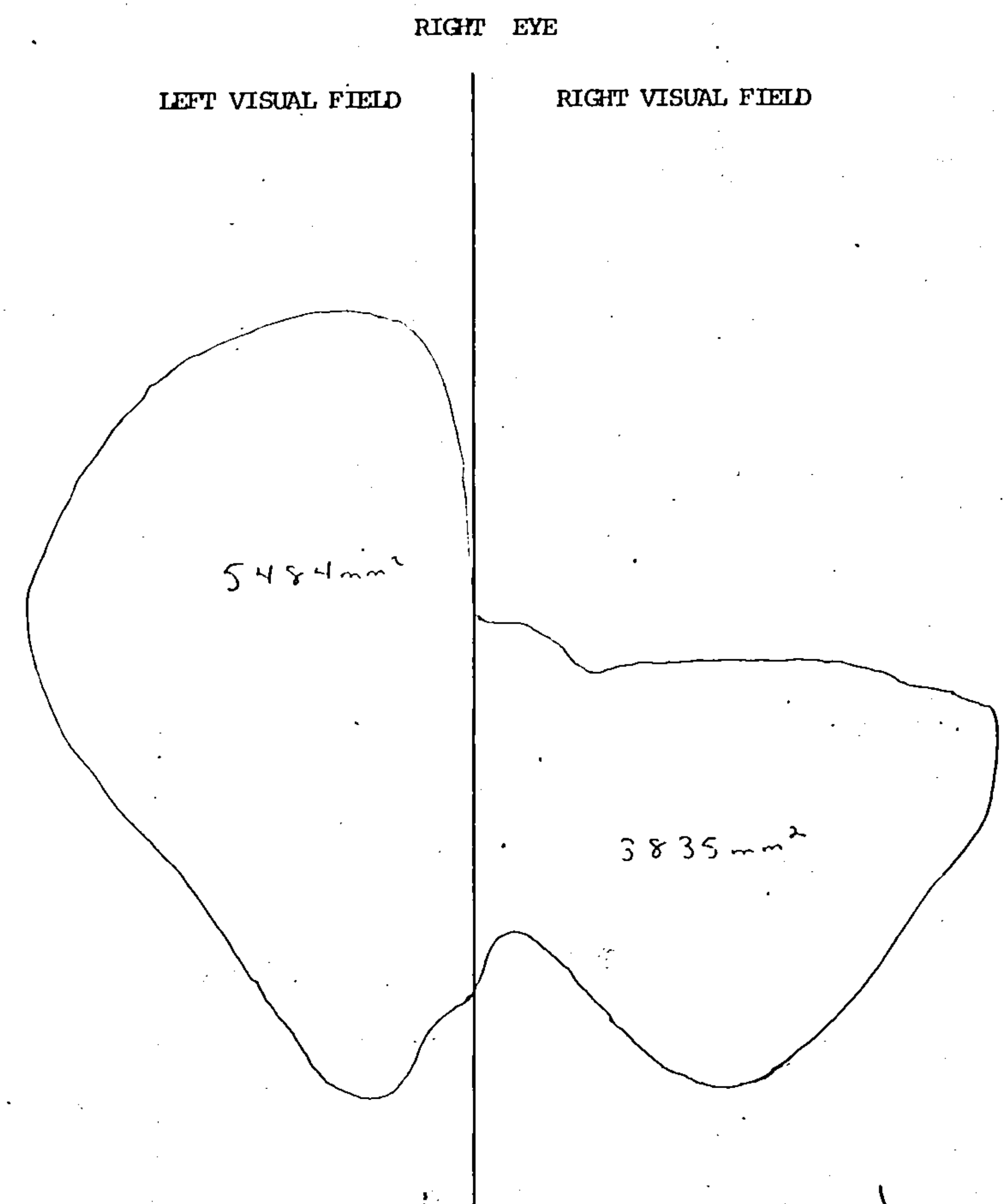
Subject El. Area of functioning visual field (measured in square millimeters) on "O2".



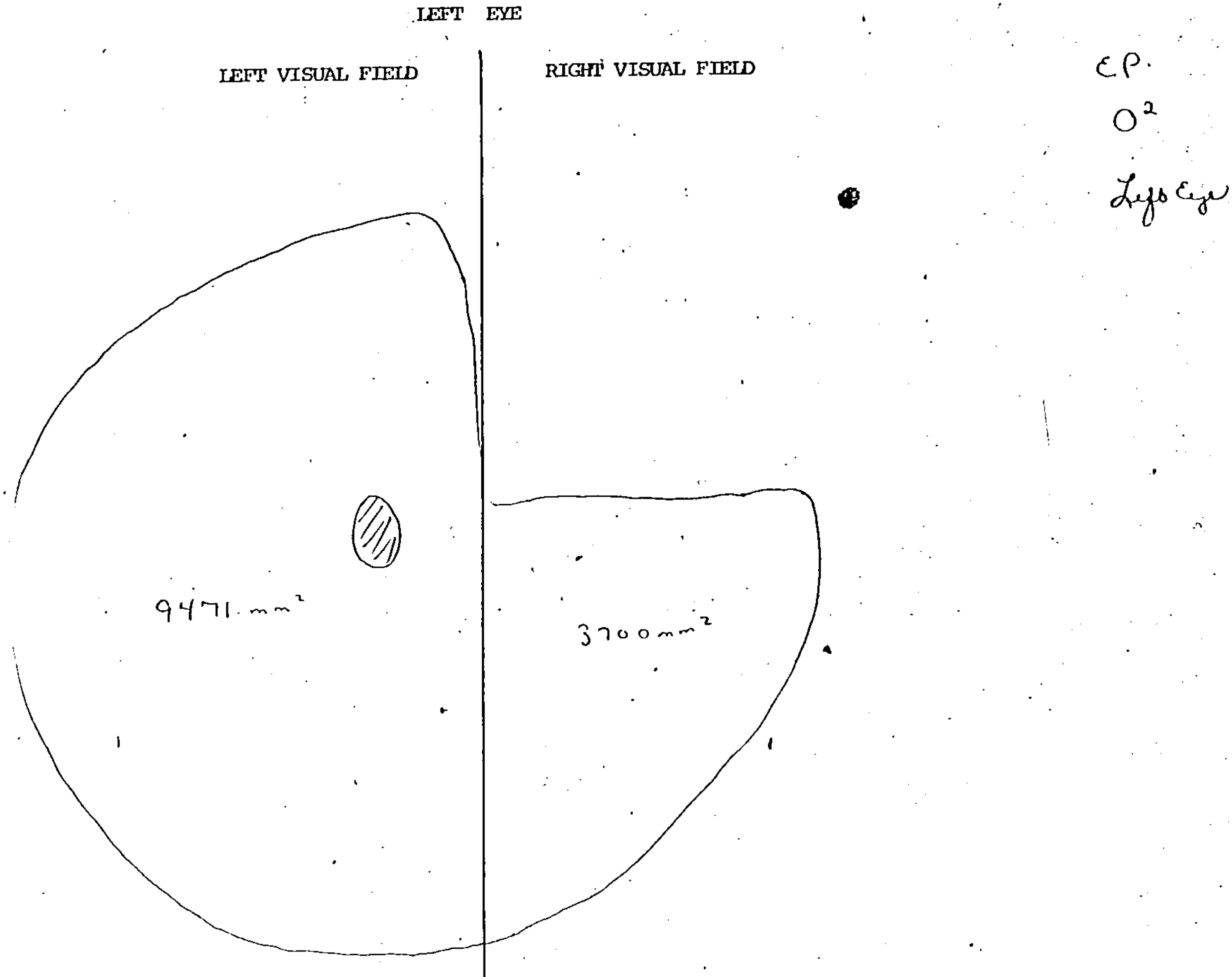
Subject E2. Area of functioning visual field (measured in square millimeters) on "O1".

O'

E.P.
Rt Eye

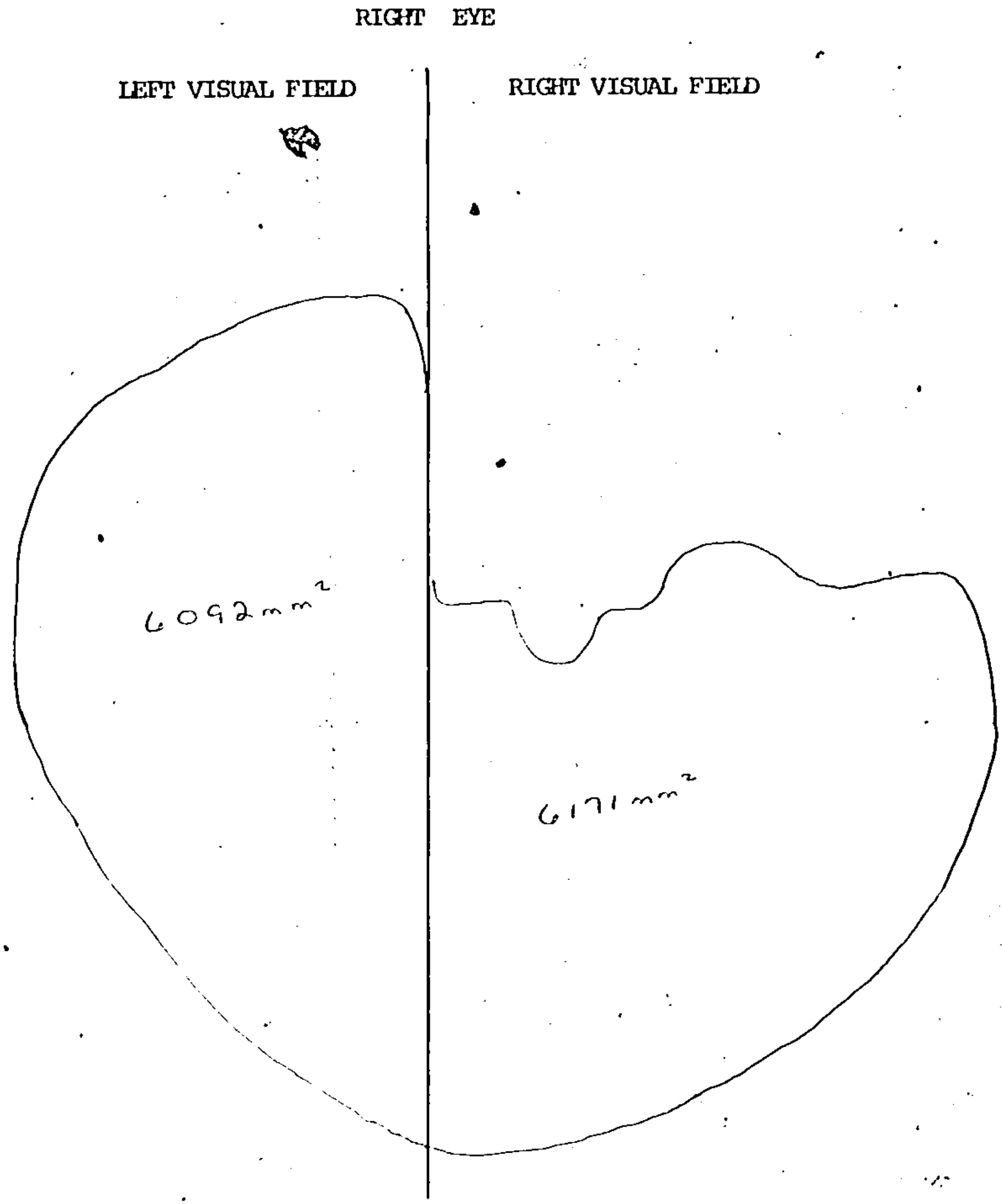


Subject E2. Area of functioning visual field (measured ~~in square~~ millimeters) on "O1".



Subject E2. Area of functioning visual field (measured in square millimeters) on "O2".

E. P.
O2
Rt. Eye



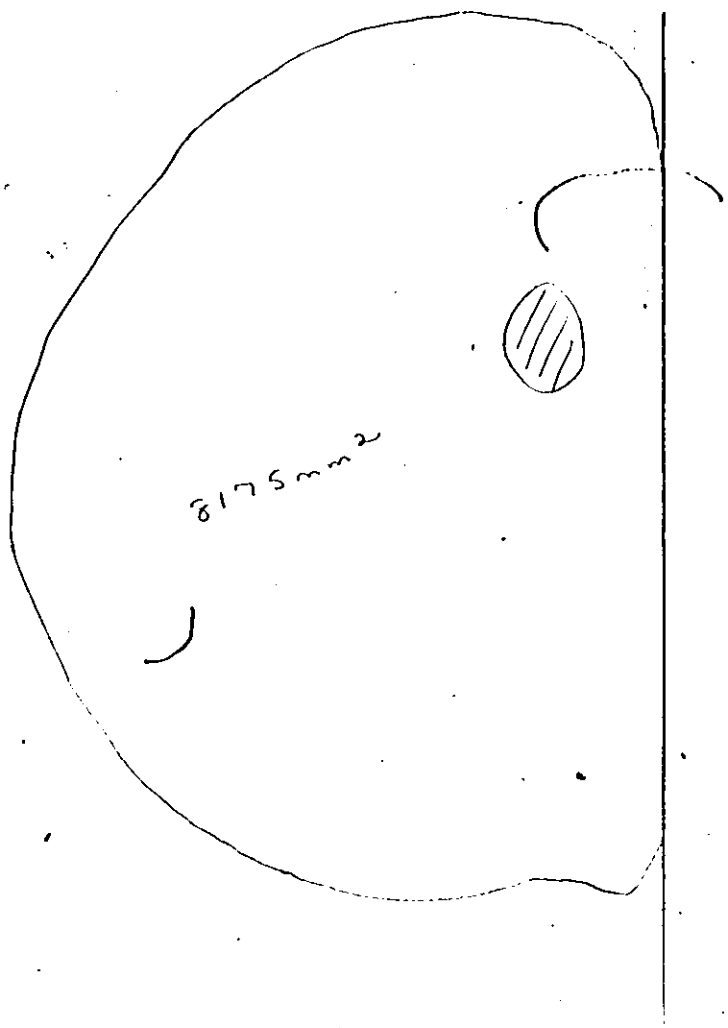
Subject E2. Area of functioning visual field (measured in square millimeters) on "O2".

$\mathcal{E}_3$ F.H. O_1

Left Eye

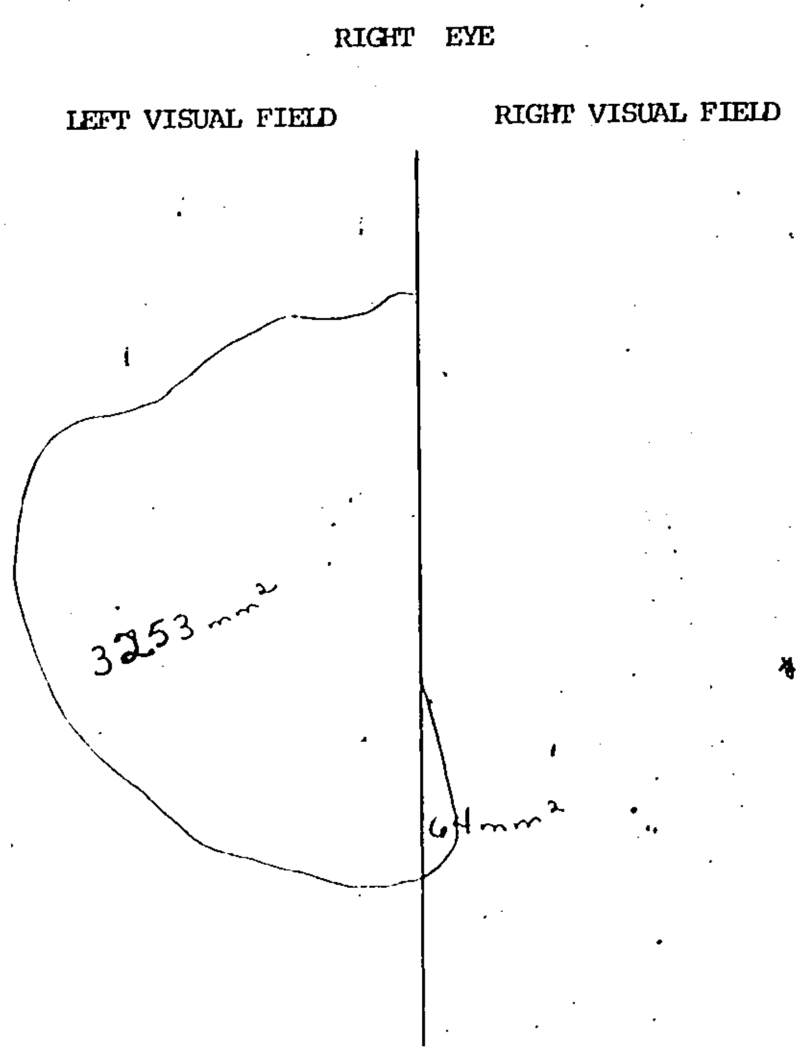
LEFT EYE

LEFT VISUAL FIELD RIGHT VISUAL FIELD



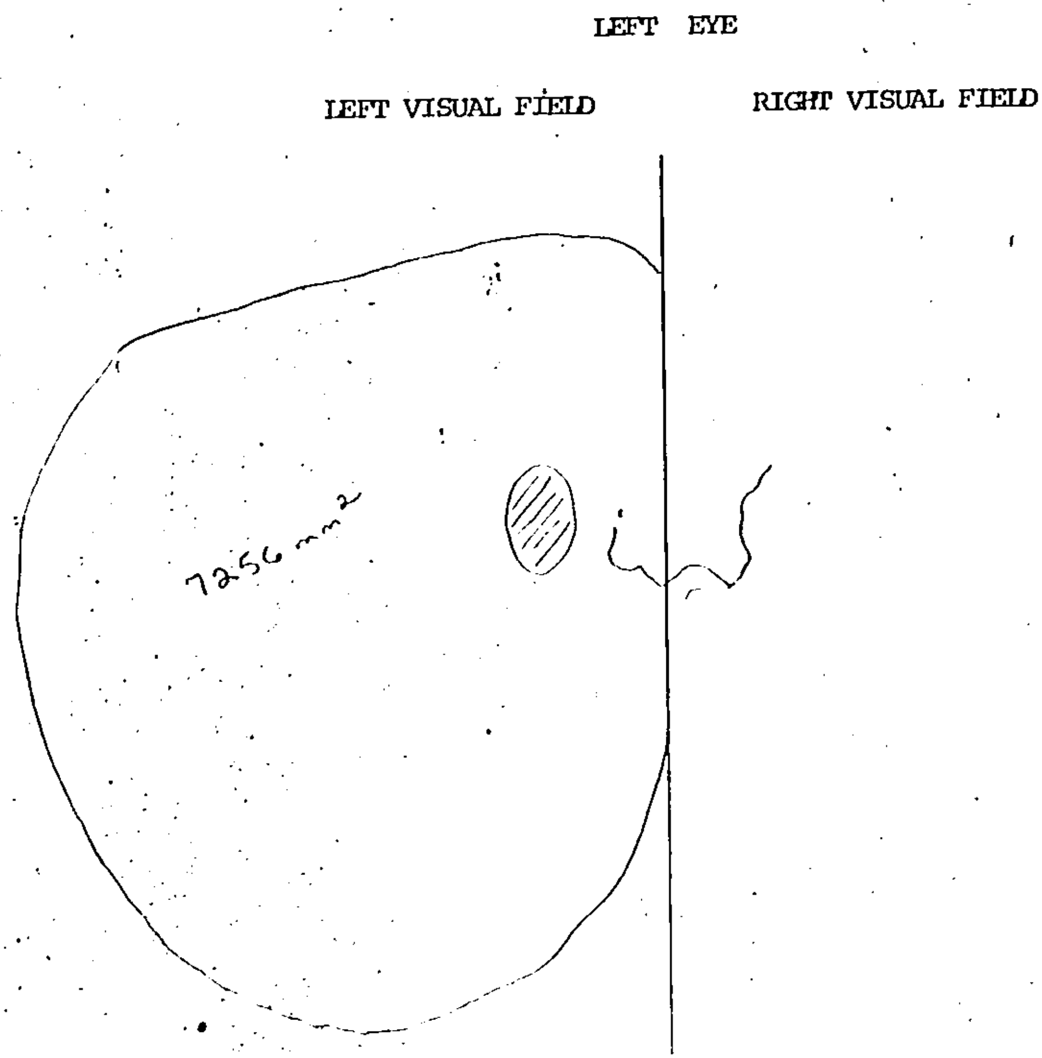
Subject E3. Area of functioning visual field (measured in square millimeters) on "O1".

E3 F.N. O. Rt. Eye



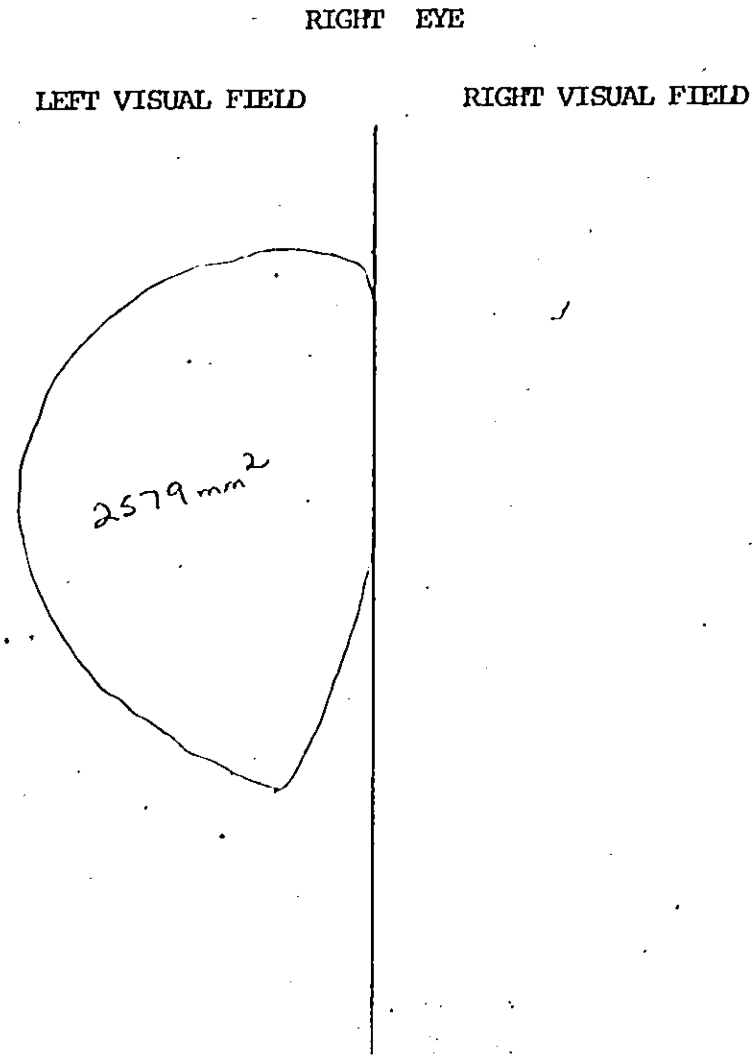
Subject E3. Area of functioning visual field (measured in square millimeters) on "O1".

F. N:
O2
L. Eye



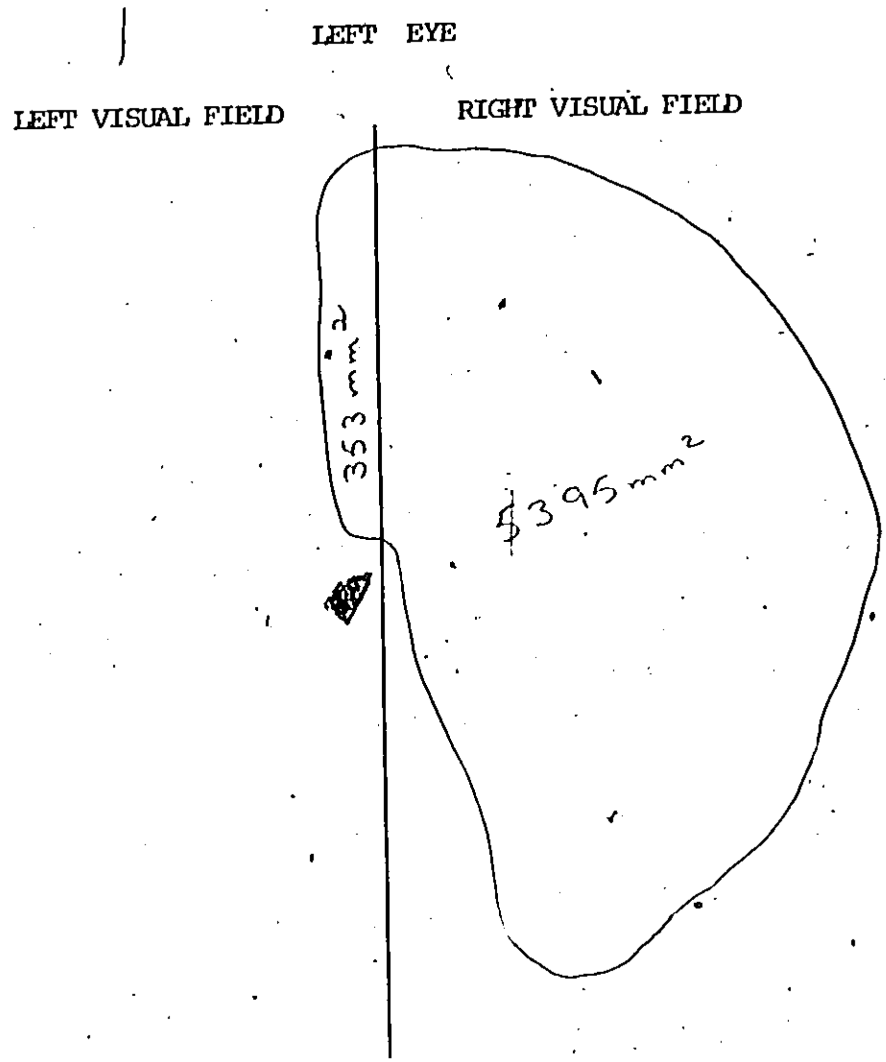
Subject E3. Area of functioning visual field (measured in square millimeters) on "O2".

F. H.
O2
Rt Eye



Subject E3. Area of functioning visual field (measured in square millimeters) on "O2".

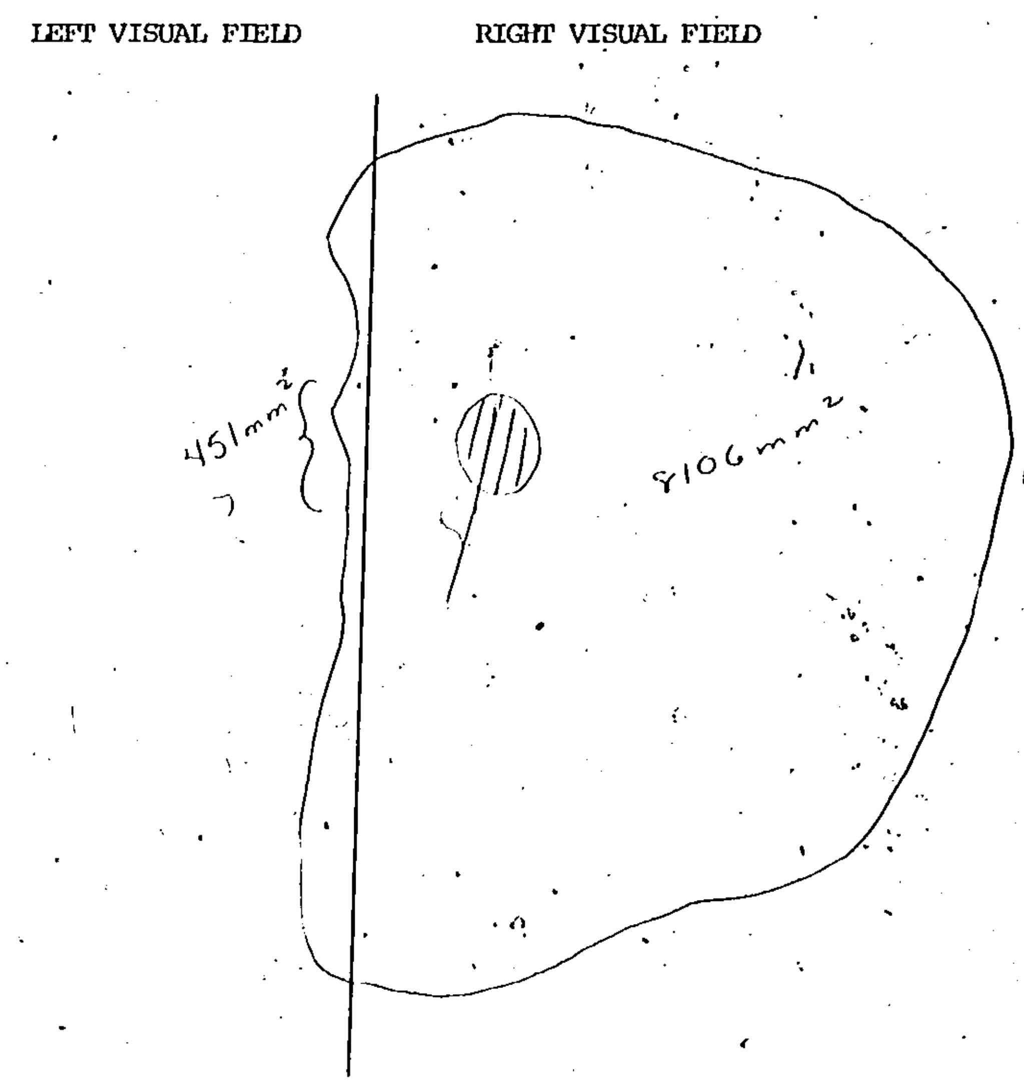
A.A.
01
Left Eye



Subject E4. Area of functioning visual field (measured in square millimeters) on "01".

AA
O1
Rt Eye

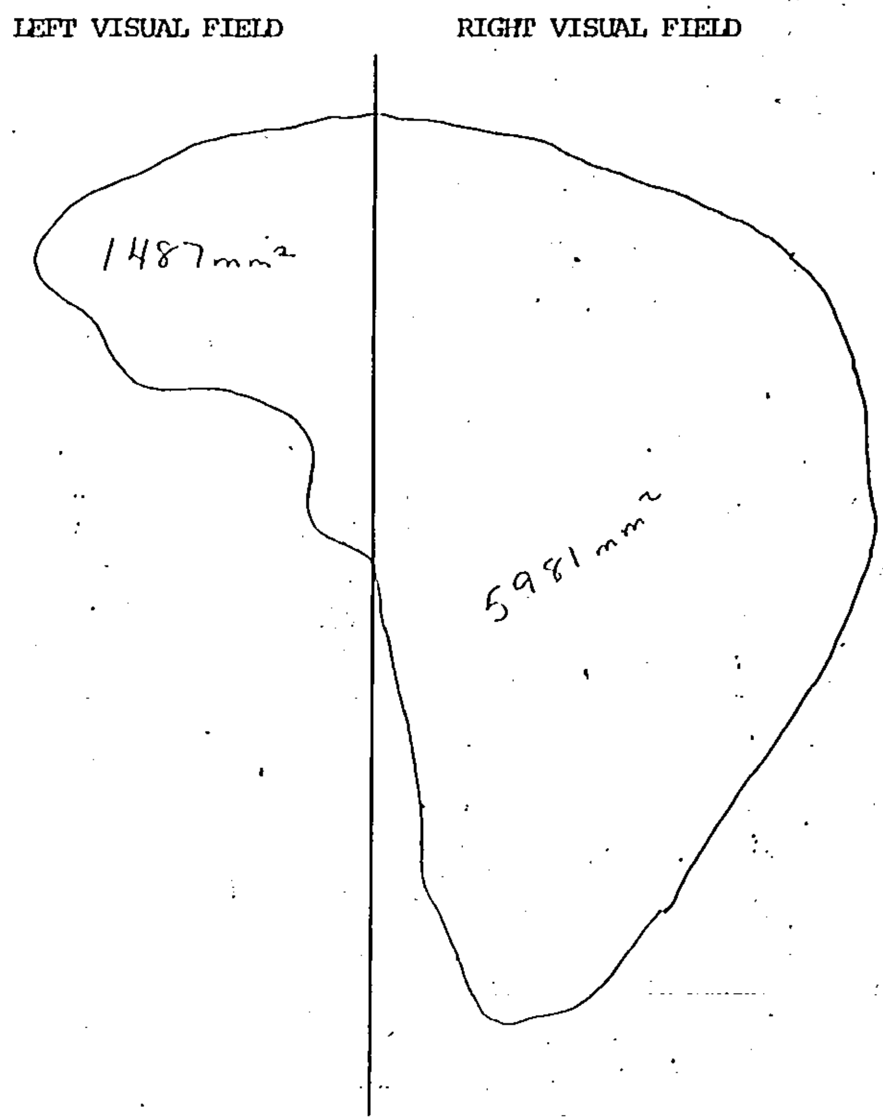
RIGHT EYE



Subject E4. Area of functioning visual field (measured in square millimeters) on "O1".

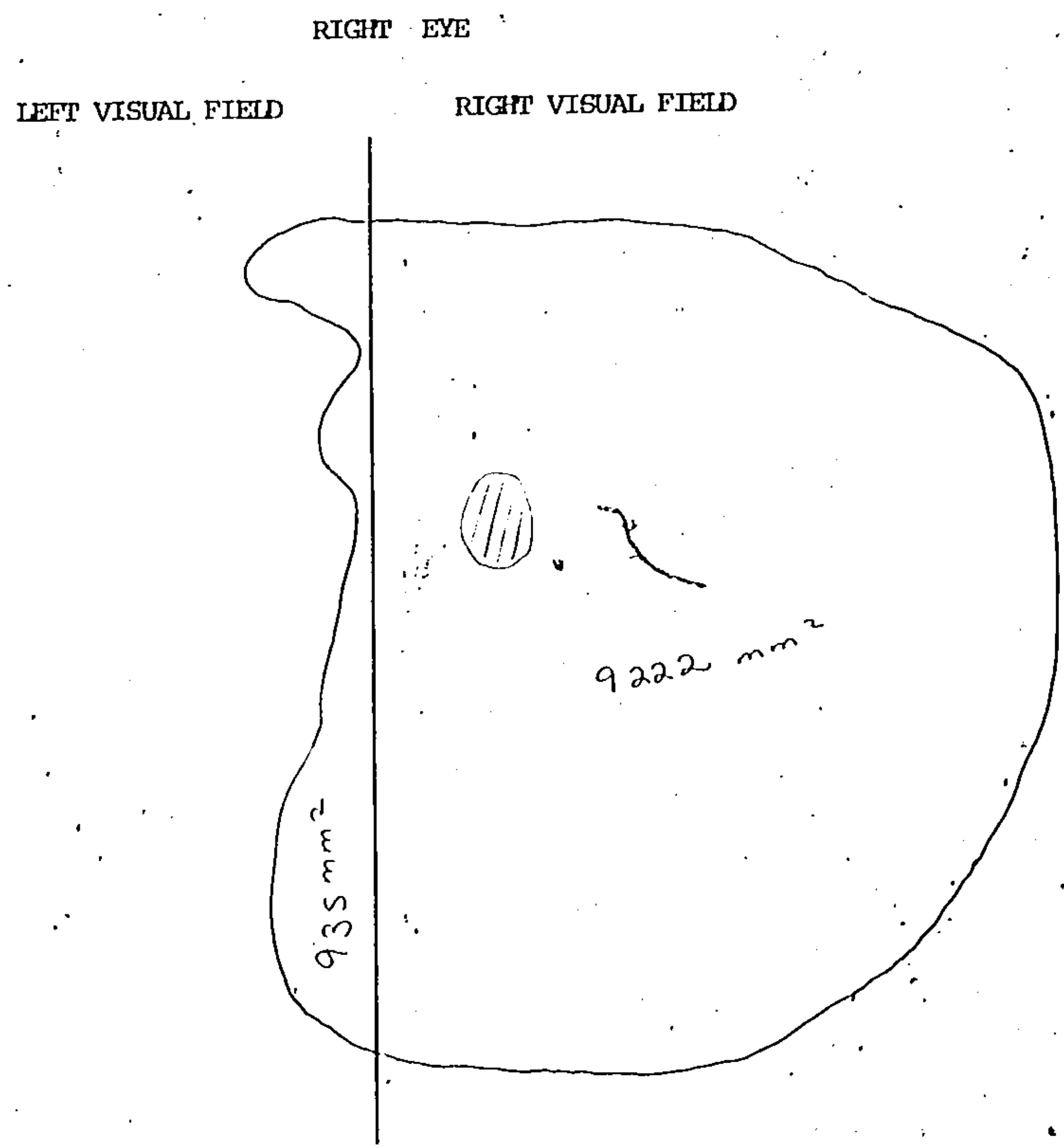
A.D. O_2
L. Eye

LEFT EYE



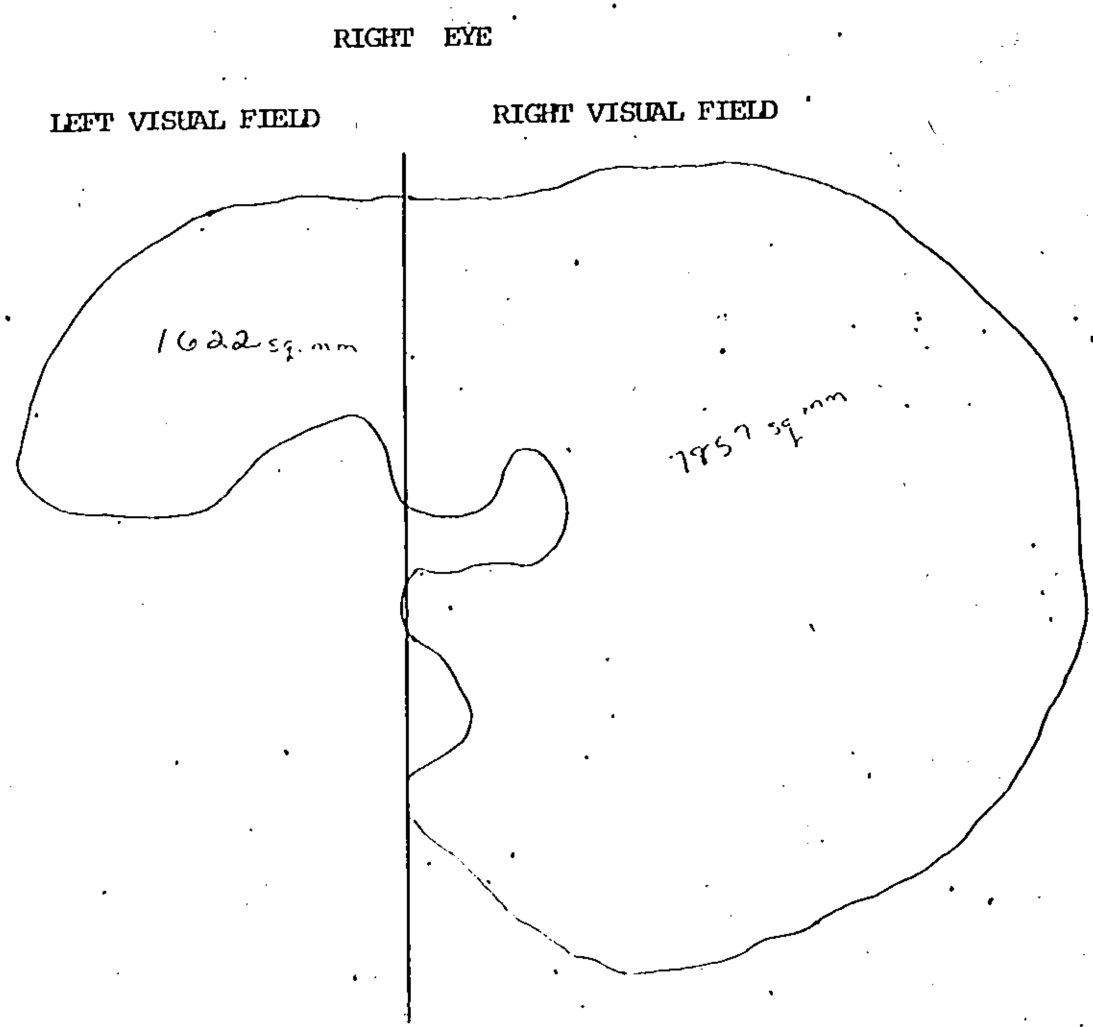
Subject E4. Area of functioning visual field (measured in square millimeters) on "O2".

A A
O2
Rb Eye



Subject E4. Area of functioning visual field (measured in square millimeters) on "O2".

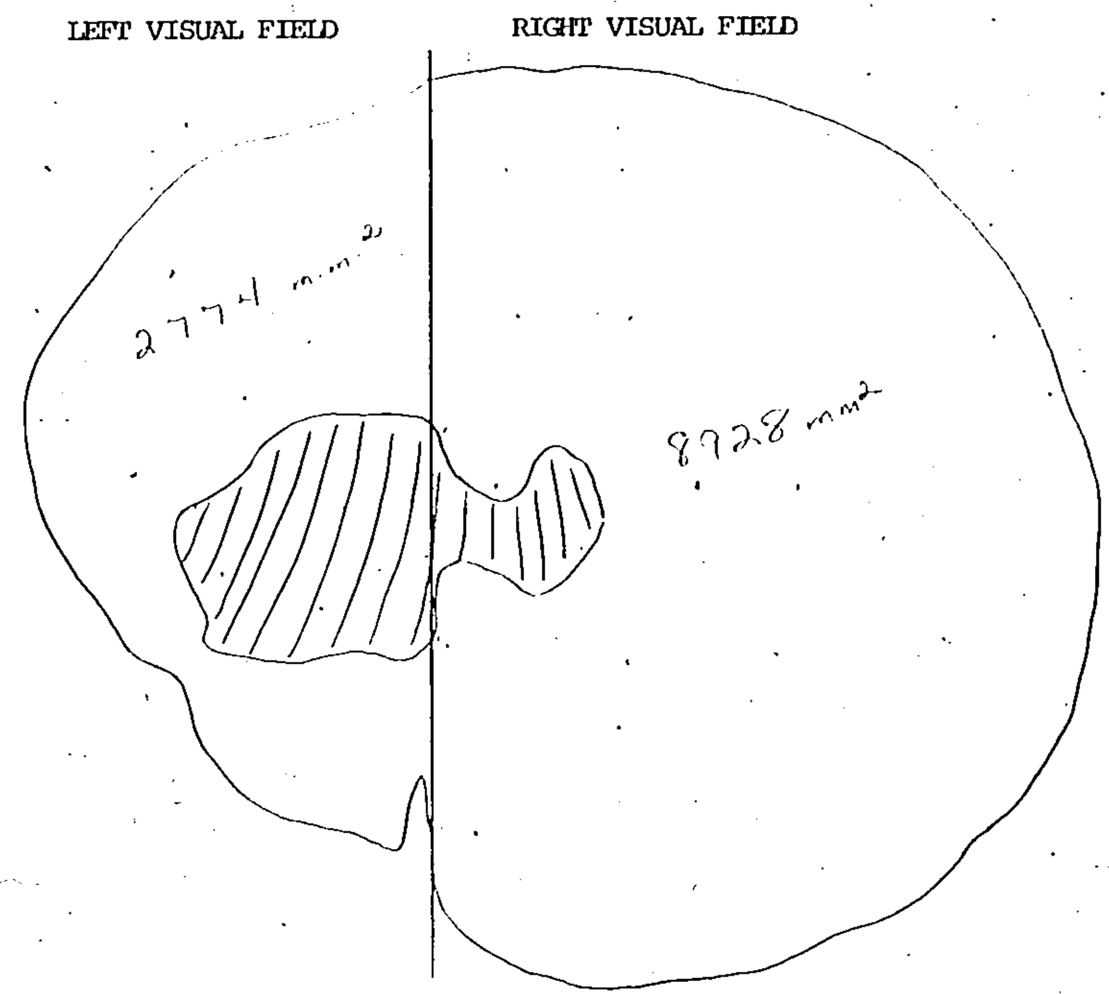
L1 — O1
R.N.
Rt Eye



Subject L1. Area of functioning visual field (measured in square millimeters) on "O1".

R.N.
O_2
Rb Eye

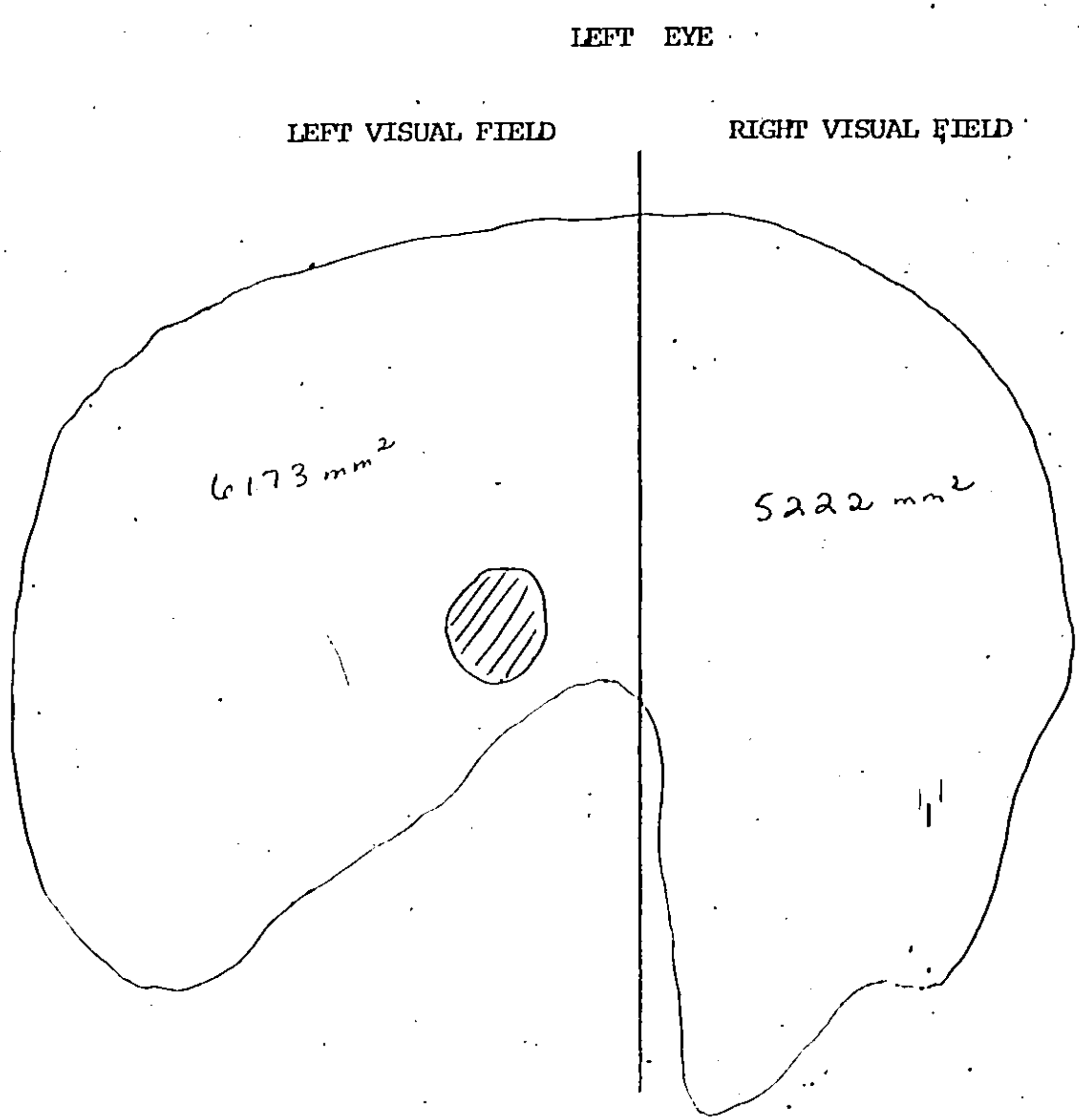
RIGHT EYE



Subject Ll. Area of functioning visual field (measured in square millimeters) on "O2".

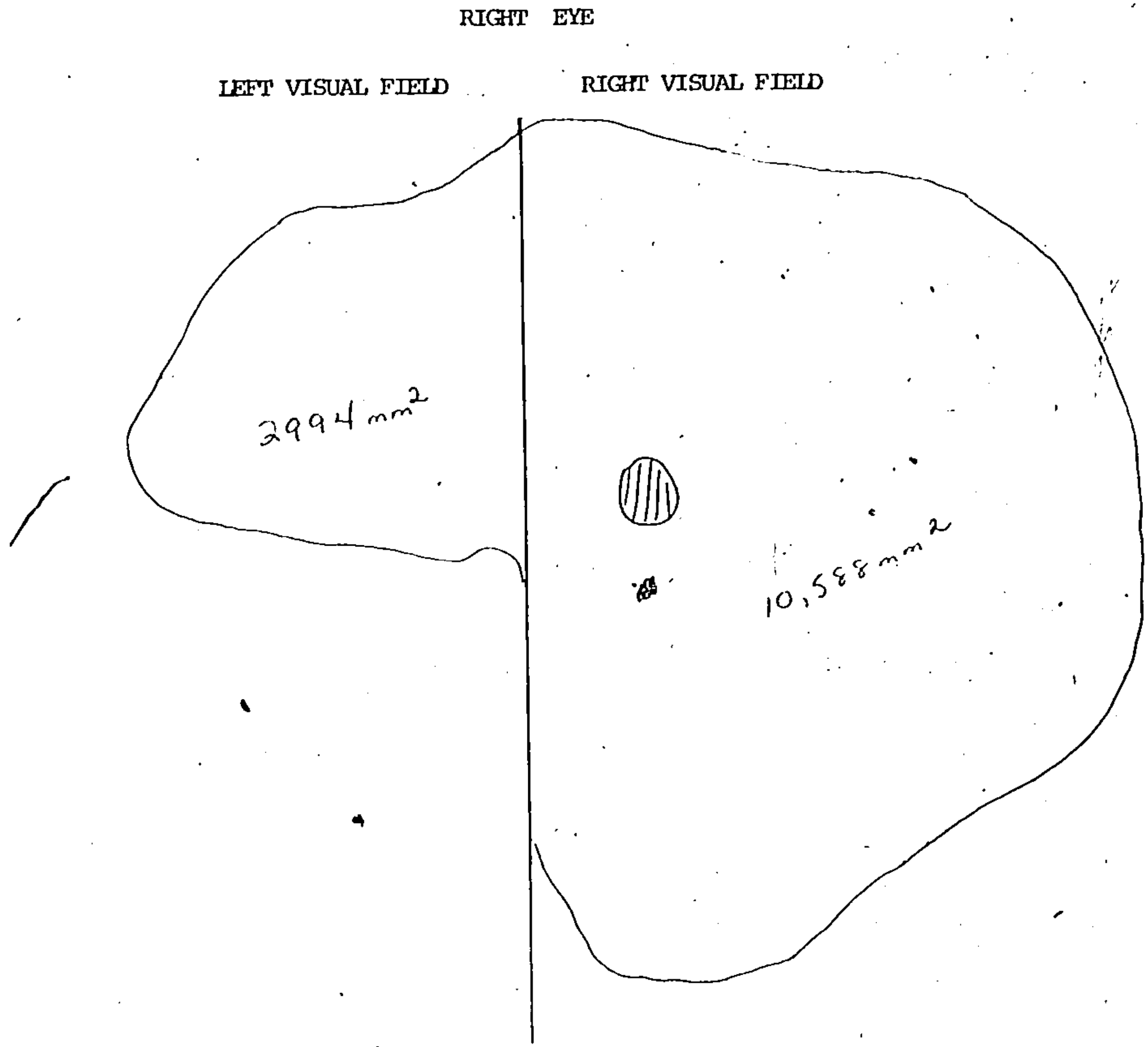
S.S. O,

Left Eye



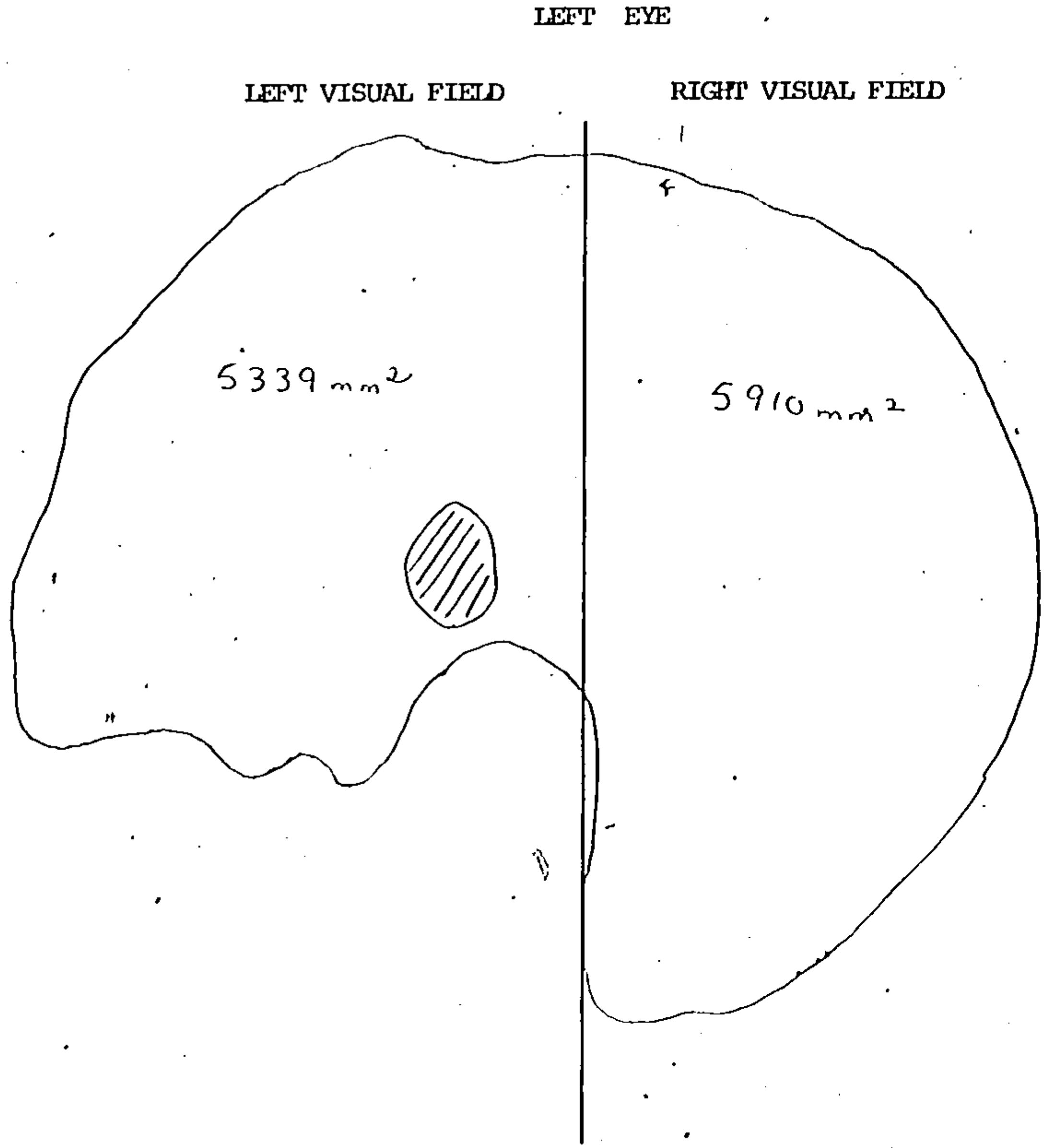
Subject L2. Area of functioning visual field (measured in square millimeters) on "Ol".

S.S. O1



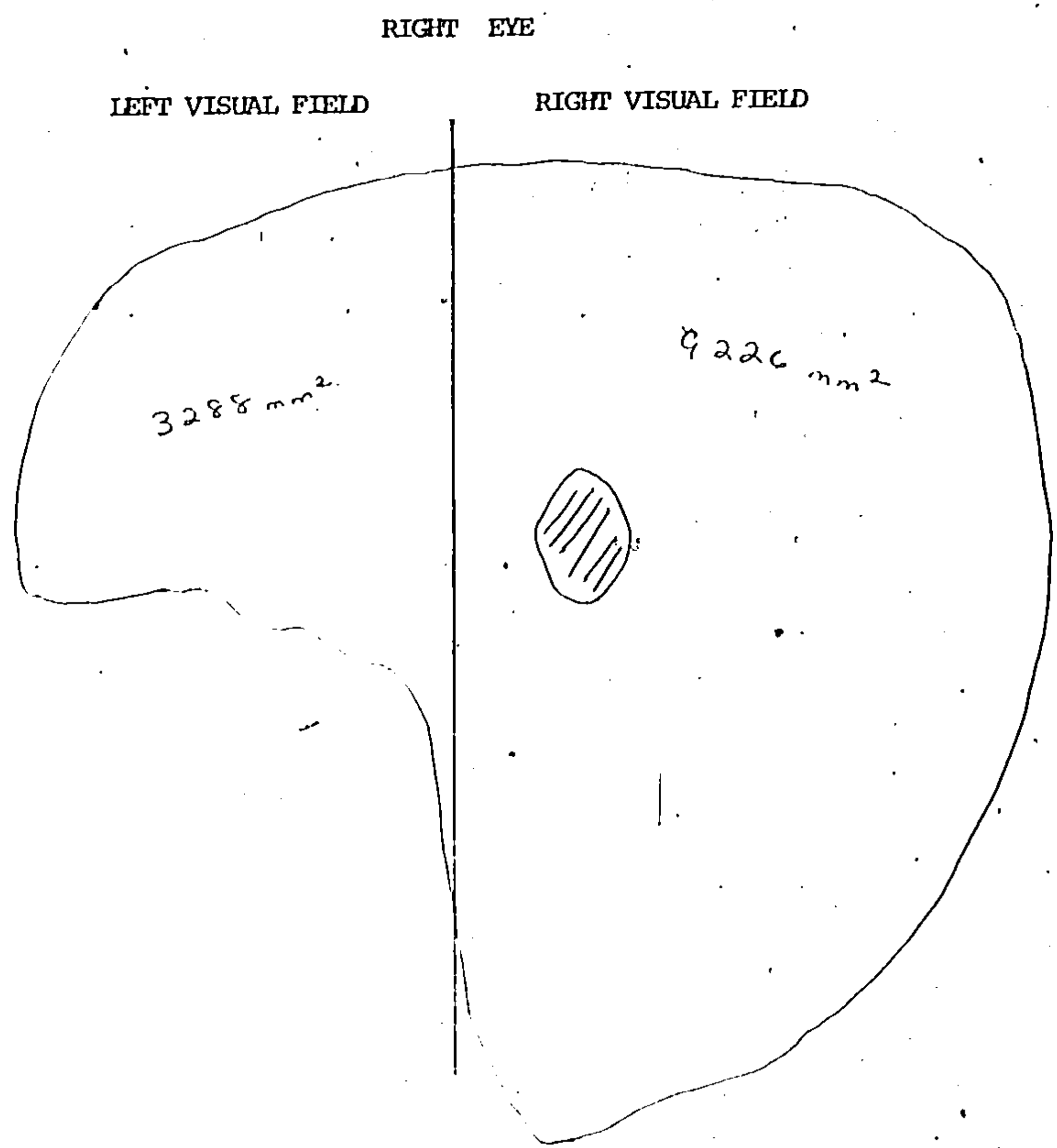
Subject L2. Area of functioning visual field (measured in square millimeters) on "O1".

J.S. O_2
Left Eye



Subject L2. Area of functioning visual field (measured in square millimeters) on "O2".

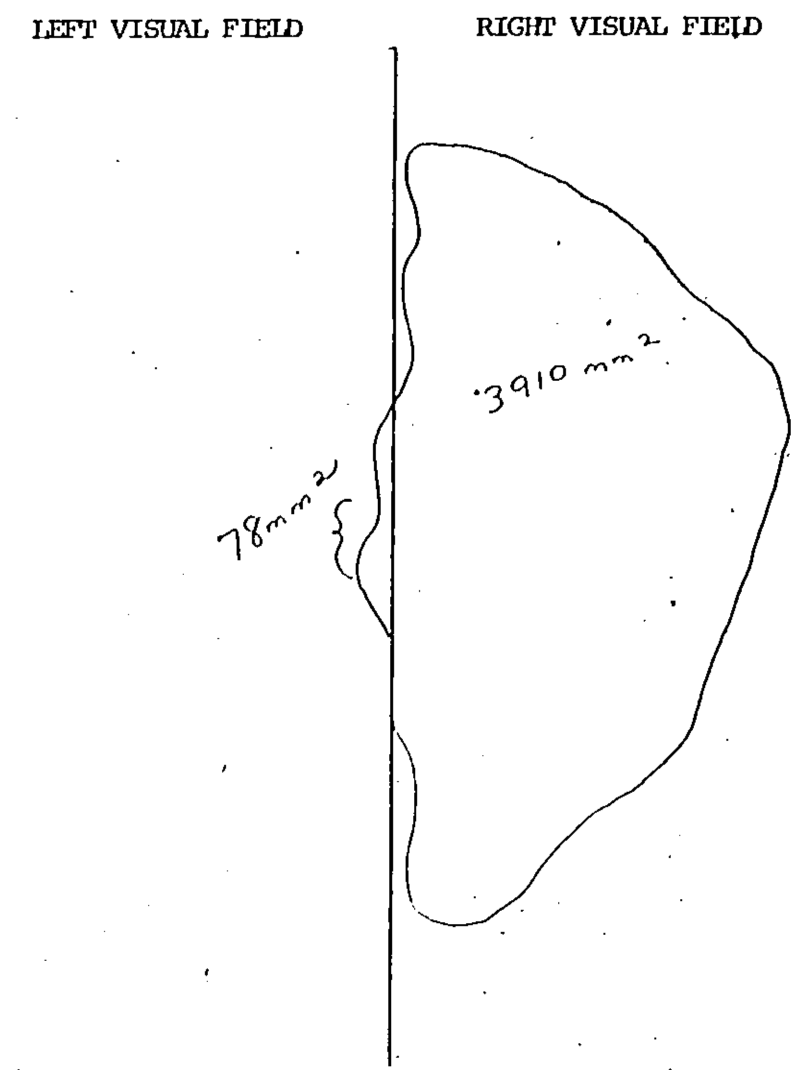
J's. O_2
Rb Eye



Subject L2. Area of functioning visual field (measured in square millimeters) on "O2".

O_1 EN
Left Eye

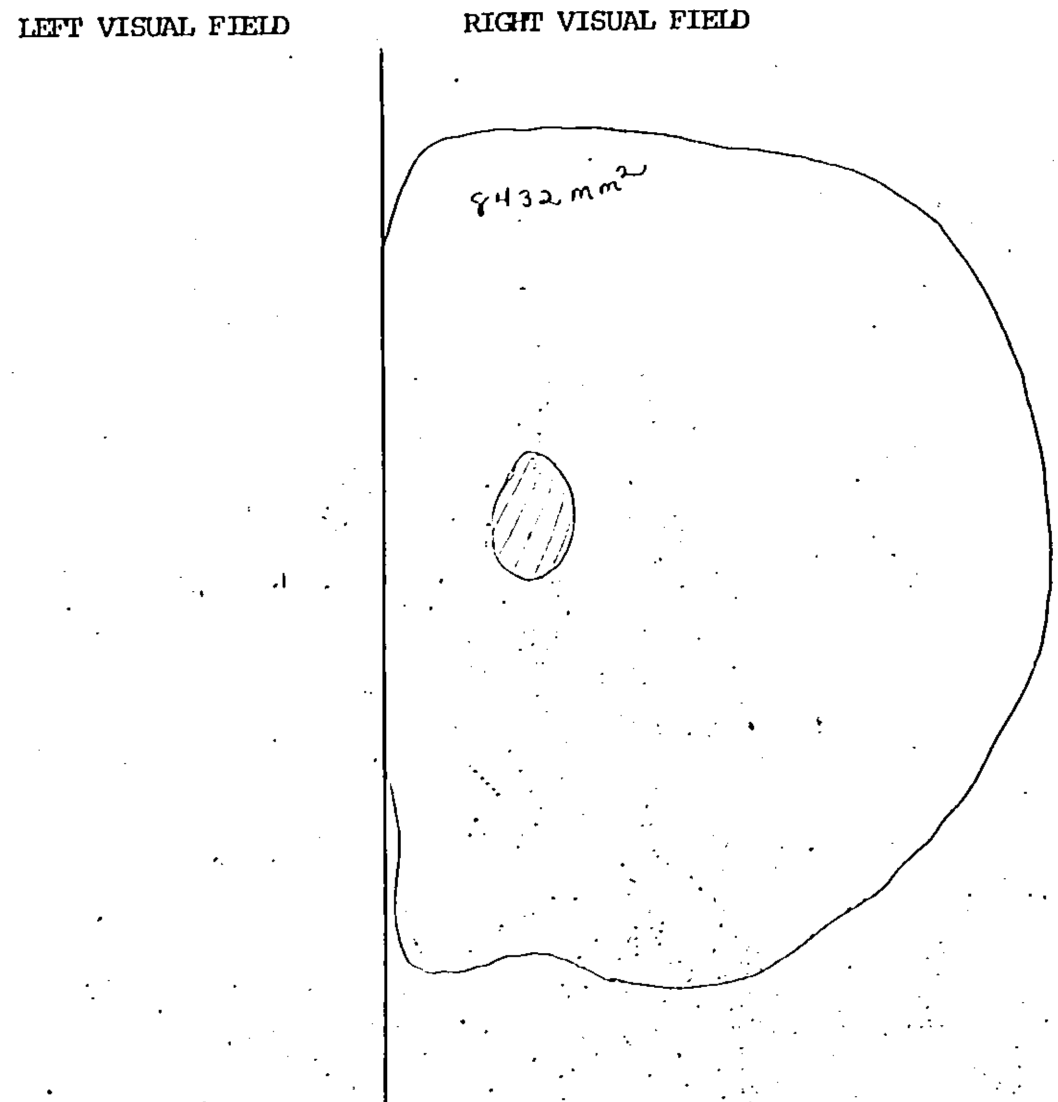
LEFT EYE



Subject L3. Area of functioning visual field (measured in square millimeters) on "O1".

EH
O1
Rb Eye

RIGHT EYE

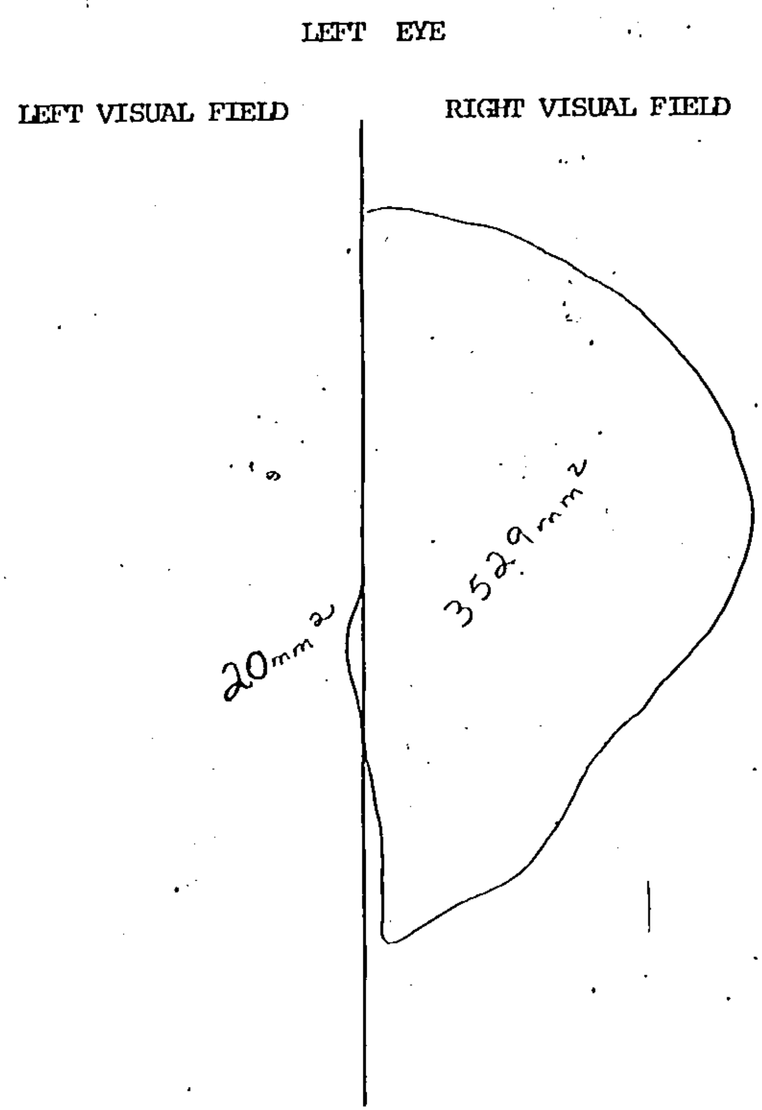


Subject L3. Area of functioning visual field (measured in square millimeters) on "O1".

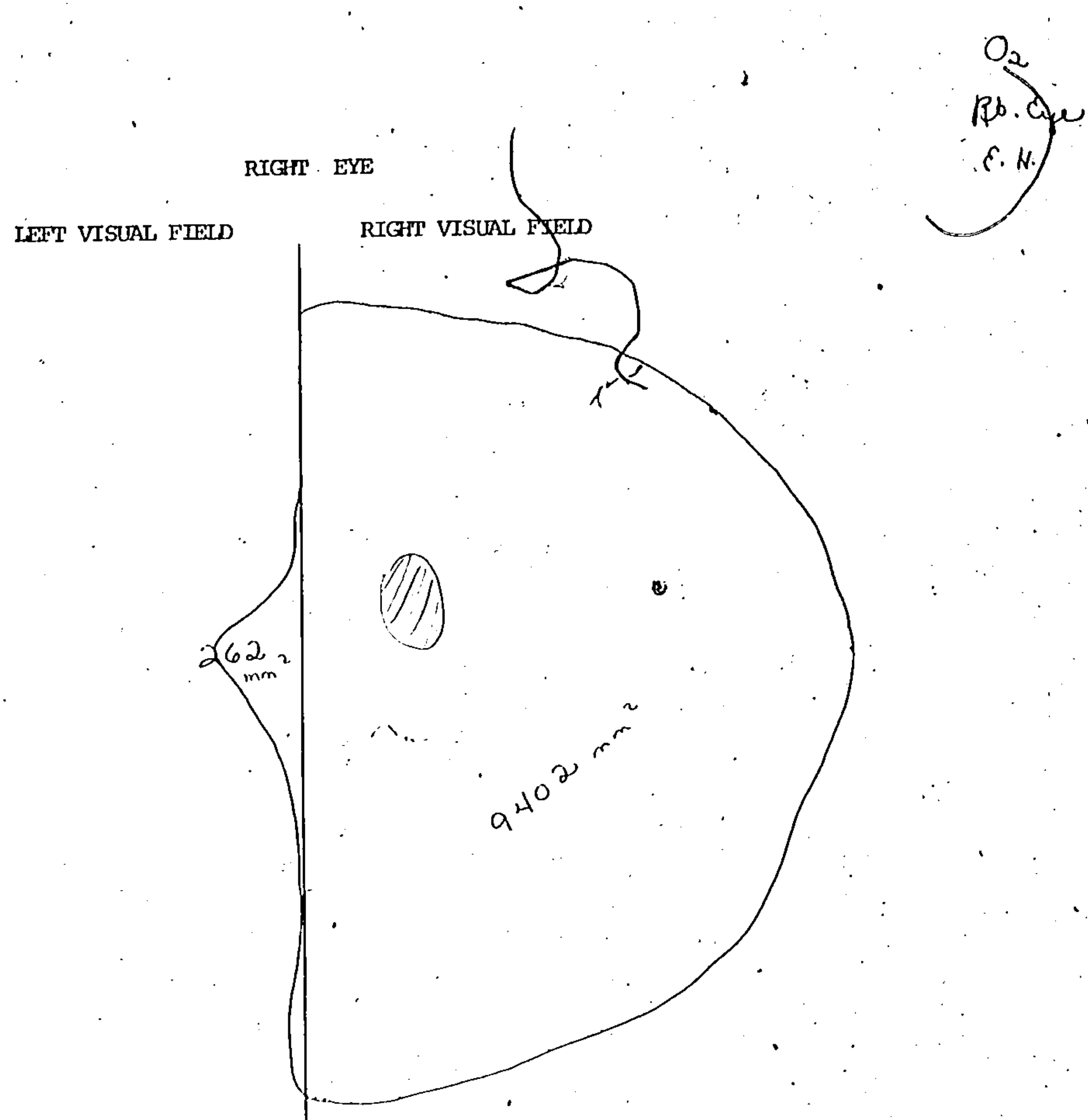
O_2

E. N.

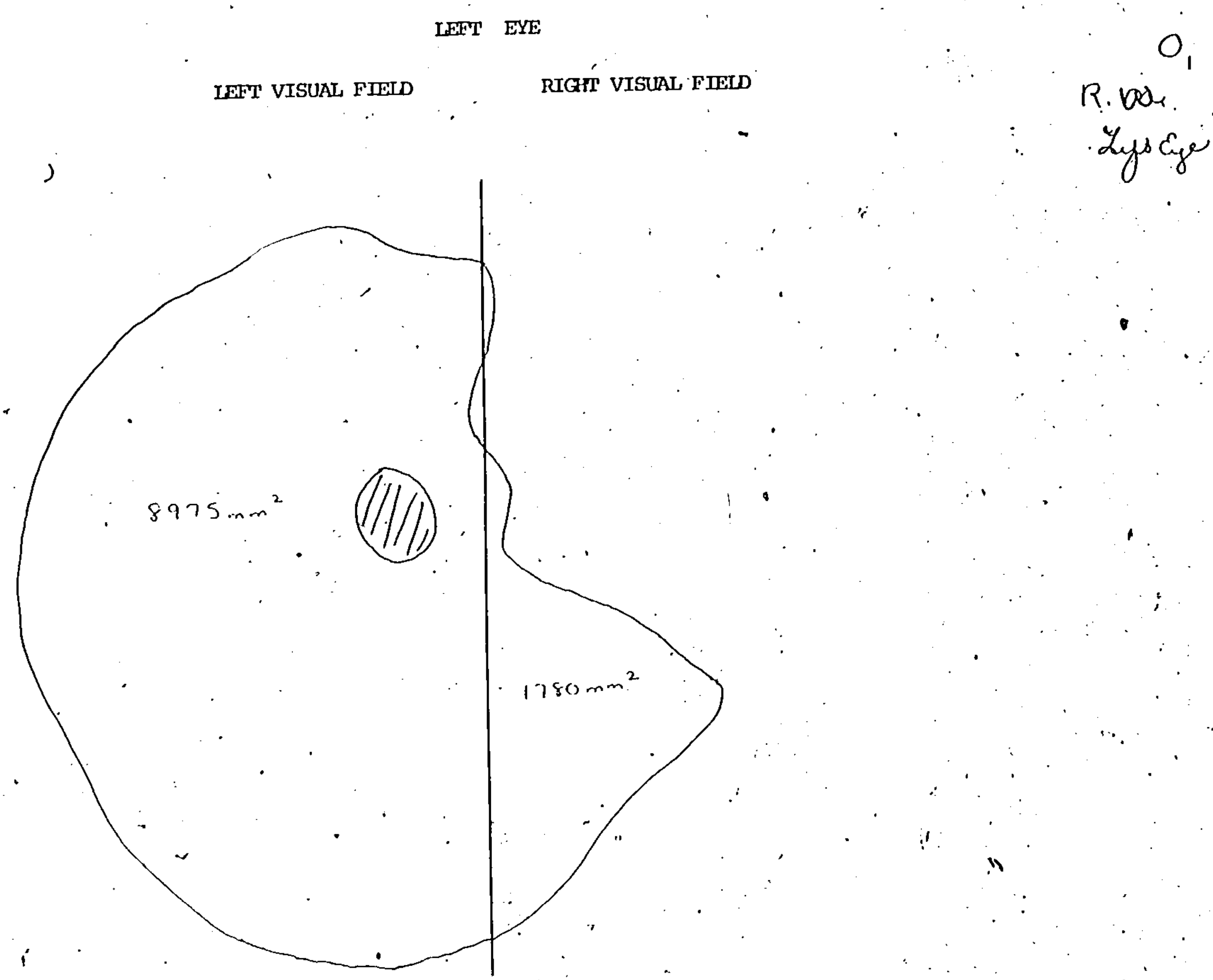
Left Eye



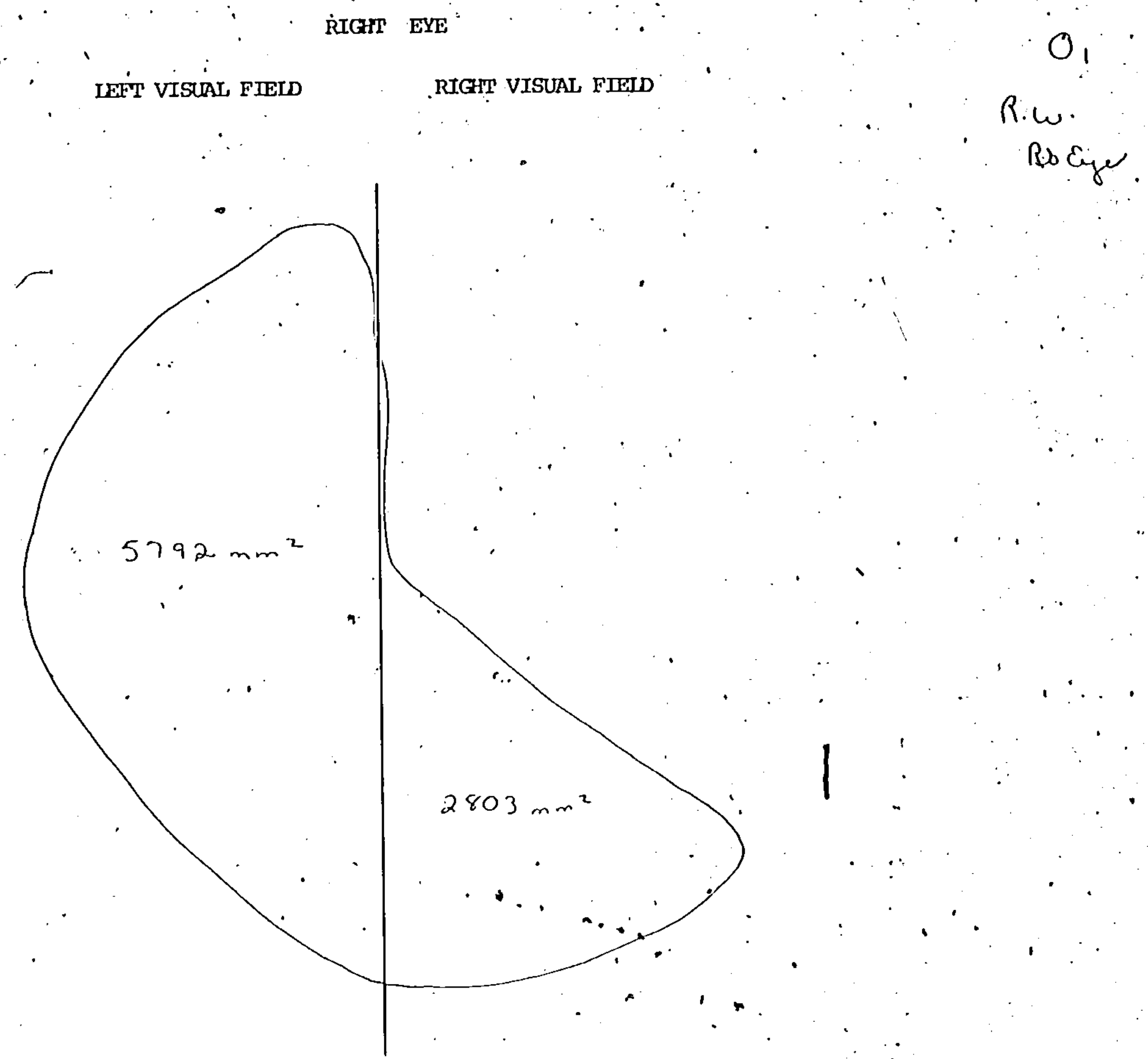
Subject L3. Area of functioning visual field (measured in square millimeters) on "O2".



Subject L3. Area of functioning visual field (measured in square millimeters) on "O2".



Subject L4. Area of functioning visual field (measured in square millimeters) on "O1".

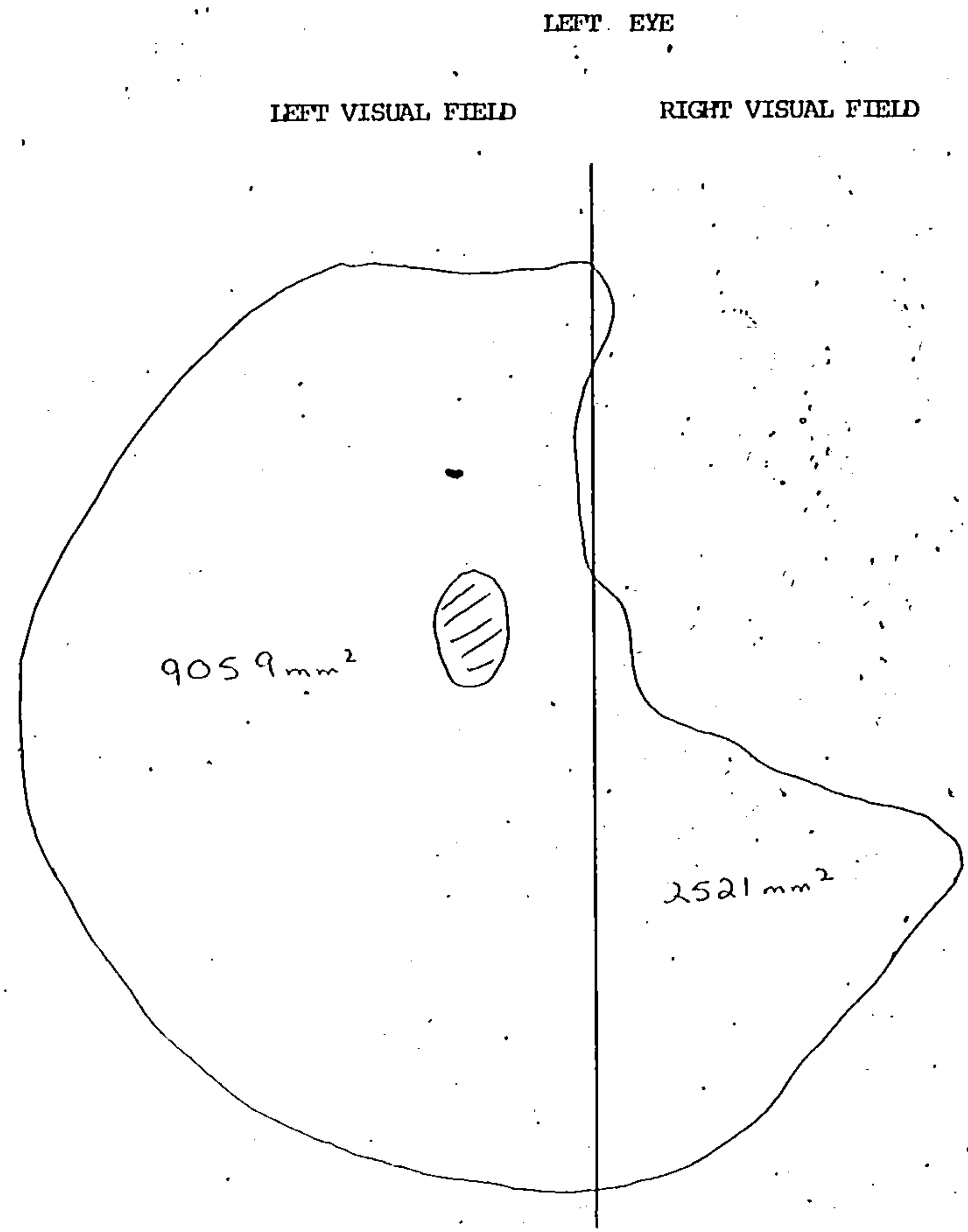


Subject L4. Area of functioning visual field (measured in square millimeters) on "O1".

O_2

R. W.

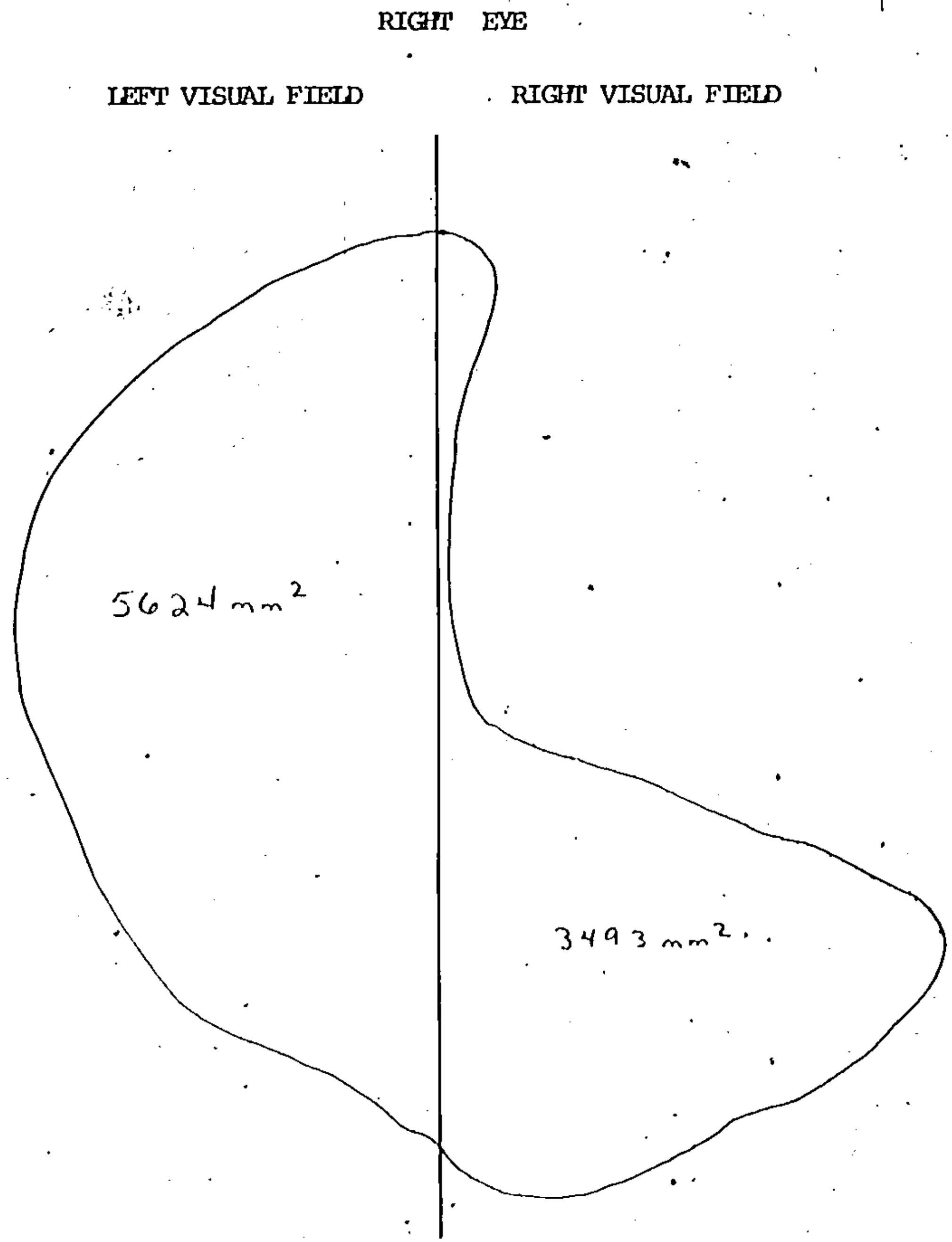
Left Eye



Subject 14. Area of functioning visual field (measured in square millimeters) on "O2".

O2

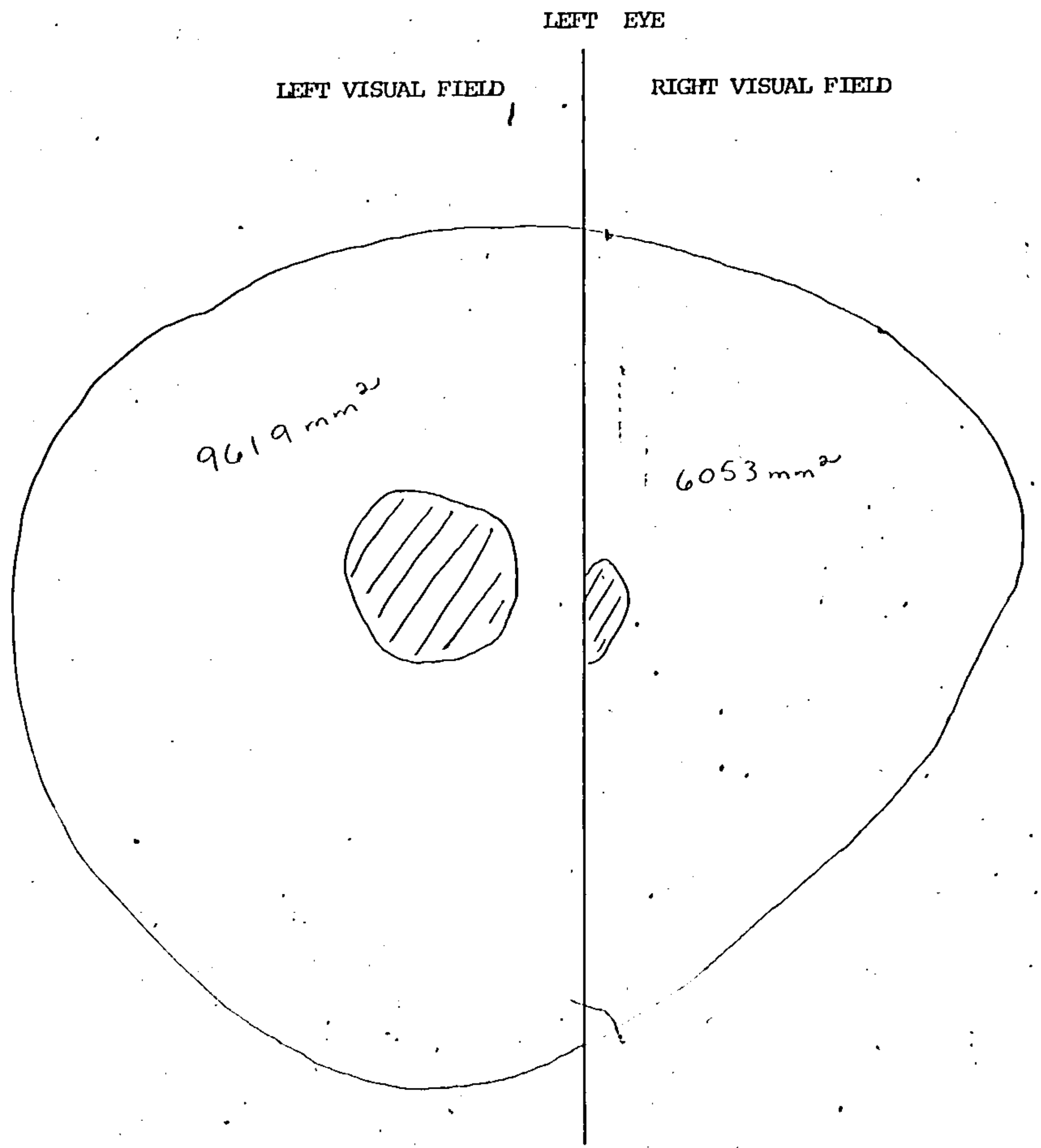
R.W.
Rt Eye



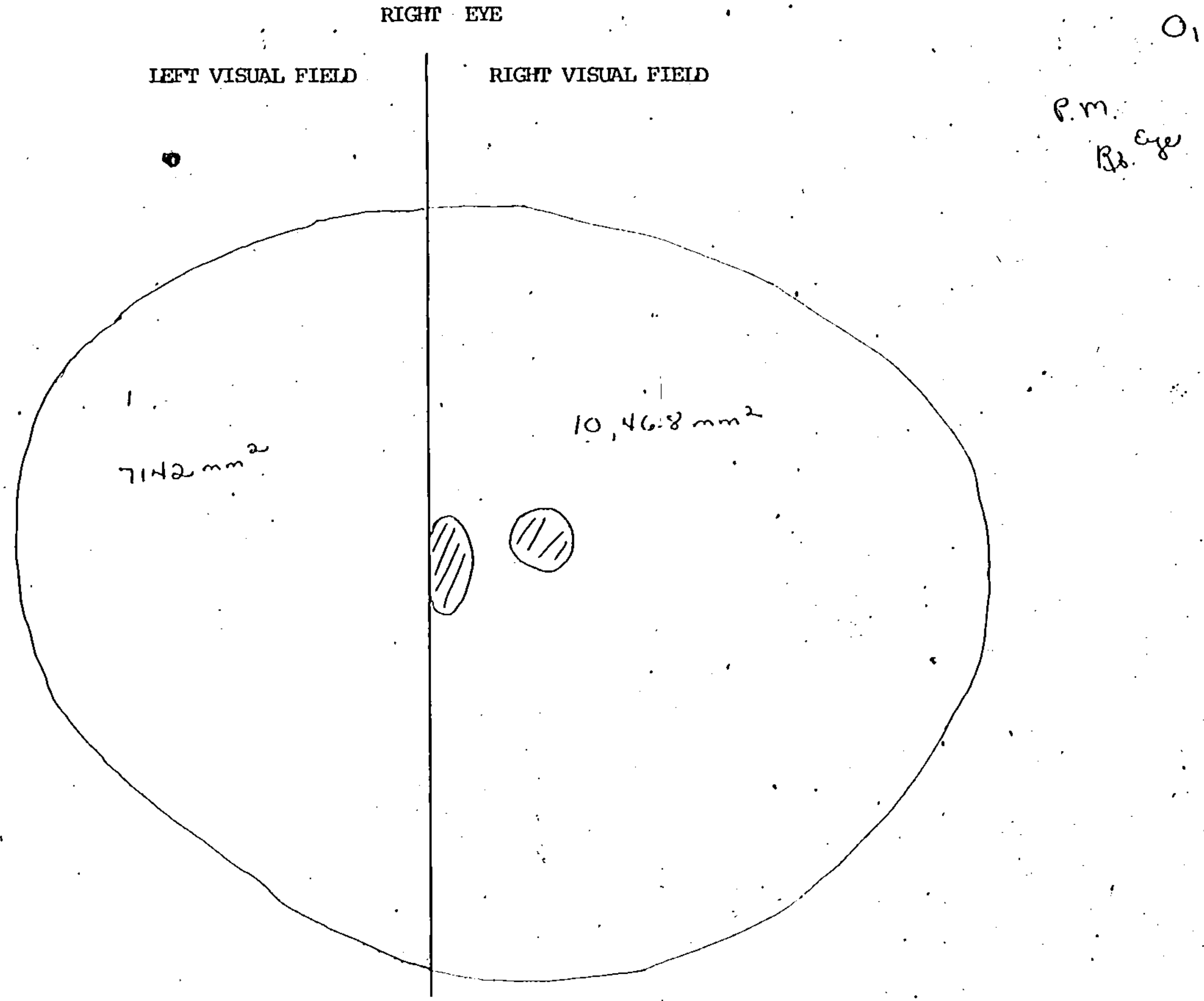
Subject L4. Area of functioning visual field (measured in square millimeters) on "O2".

O1

P.M.
Left Eye



Subject L5. Area of functioning visual field (measured in square millimeters) on "O1".

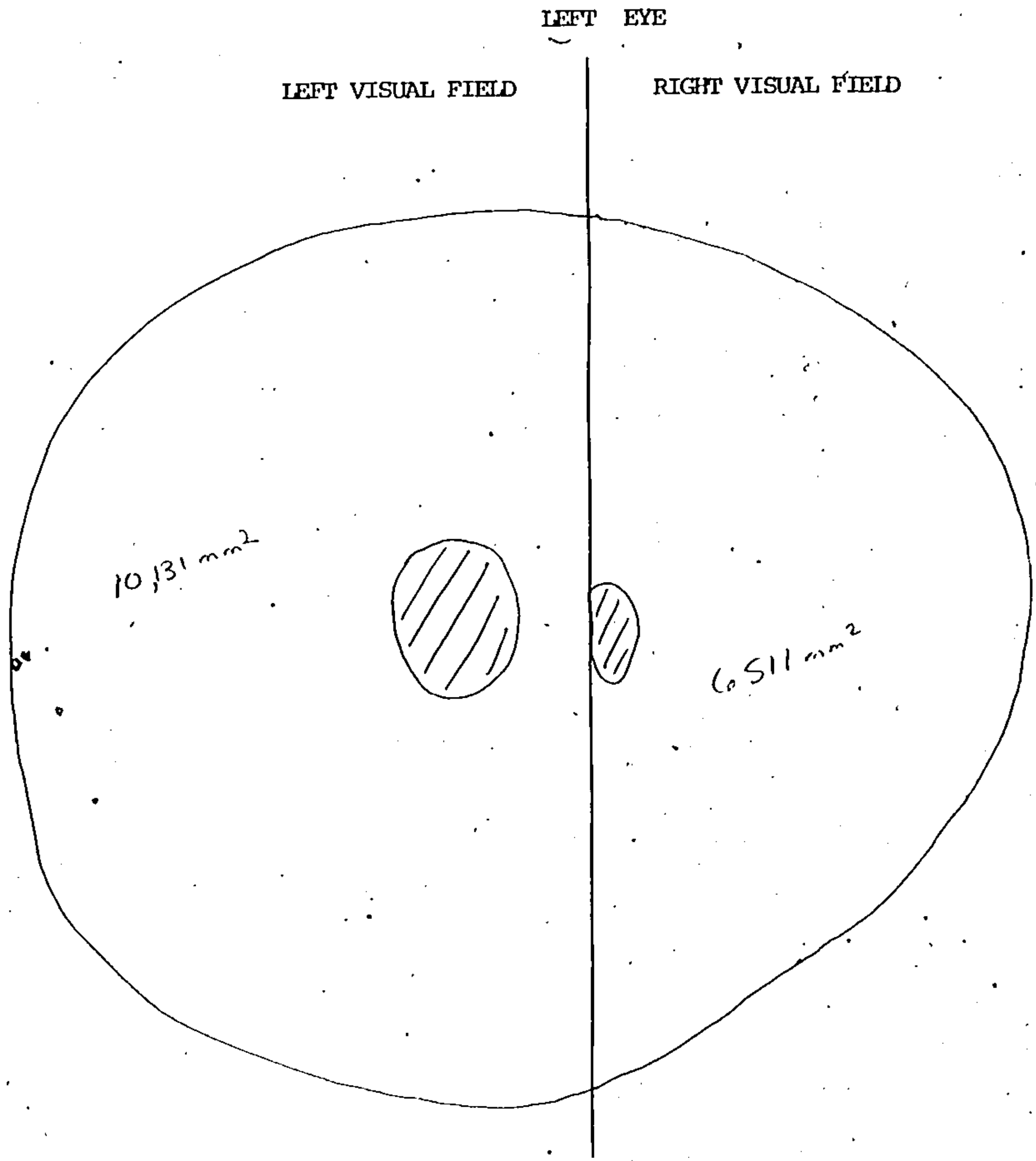


Subject L5. Area of functioning visual field (measured in square millimeters) on "O1".

O_2

P. M.

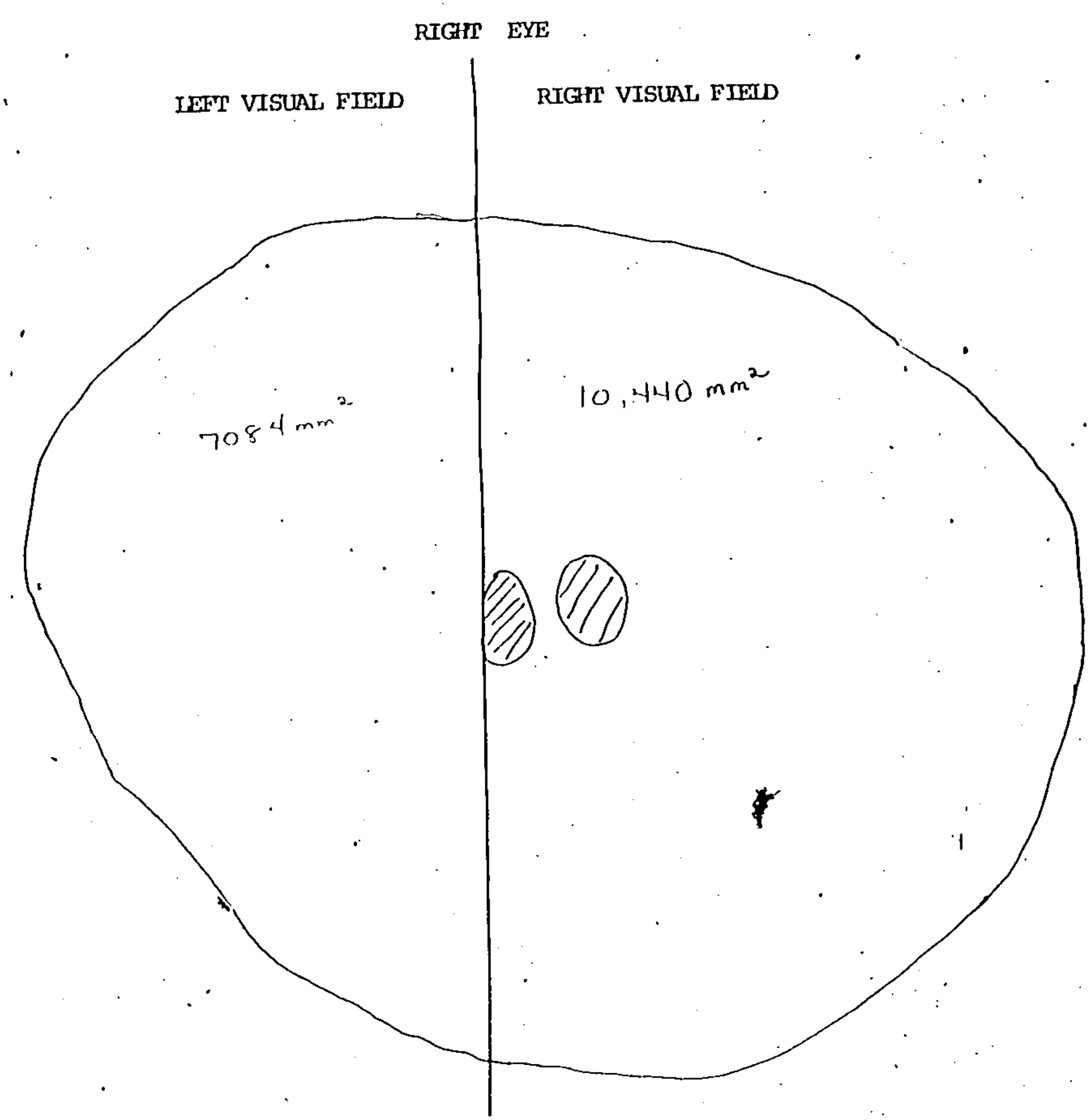
Left Eye



Subject L5. Area of functioning visual field (measured in square millimeters) on "O2".

O2

P.M.
Rb Eye



Subject L5. Area of functioning visual field (measured in square millimeters) on "O2".

VITA AUCTORIS

1952	Born in Siloam Springs, Arkansas, U.S.A. to Margie Donna and Norman Edward Burkhart.
1958-1966	Primary education obtained in Ohio and Michigan public school systems.
1970	Graduated from Wade Hampton High School, Greenville, South Carolina.
1974	Graduated from Calvin College, Grand Rapids, Michigan. Bachelor of Arts Degree. Major in Psychology and Speech-Communication.
1977	Graduated from University of Waterloo, Waterloo, Ontario. Masters of Applied Science in Psychology.
1977-1980	University Hospital, London, Ontario. Staff Psychometrist supervised by Drs. Doreen Kimura and J. McGlone.
1977-1980	University of Western Ontario, London, Ontario. Advanced Graduate Study in Physiological Psychology.
1982	Montreal Neurological Institute, Montreal, Quebec. Summer Intern.
1982-1983	Henry Ford Hospital, Detroit, Michigan. A.P.A. approved internship in Psychology.
1980-1985	University of Windsor, Windsor, Ontario. Graduate Student in Human Clinical Neuropsychology.